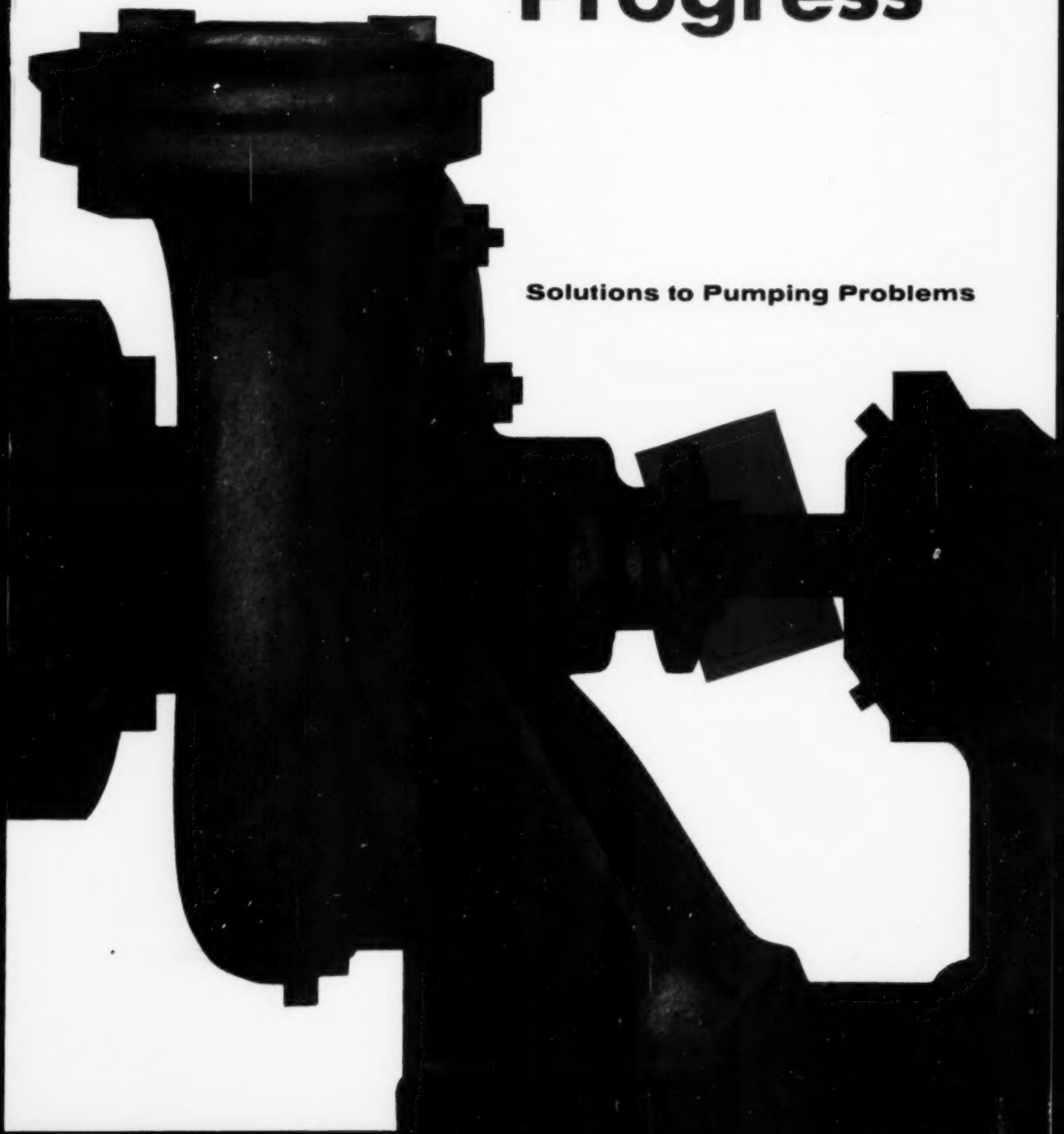
Chemical Engineering Progress

SEPTEMBER 1954



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Chemical Engineering Progress

SEPTEMBER, 1954

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this month's cover

The pumping of materials-in-process often brings on difficulties arising from the point of entry of the rotating shaft through the casing. Author Mitchell of Du Pont recommends improving or replacing sealing devices . . . co-authors Litzenberg and White tell how their firm has done the latter . . . co-authors Savage and Cobb tell about doing the former for high temperature service! In addition, four manufacturers report on recent adaptations and developments. September C.E.P., needless to say, features pumps.

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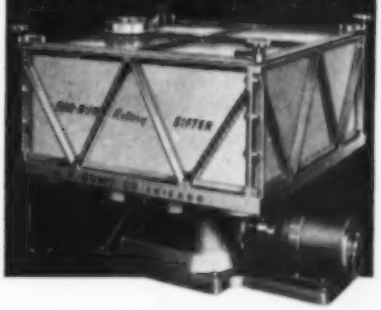
Better Sifting Better Grading
OF DRY MATERIALS



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The Bar-Nun Rotary Sifter is a compact, self-contained, motor-driven unit for making particle-size separations on most all dry, powdered, granular, flaked or crystalline materials. The smooth, vibrationless operation requires less power and contributes to long life and low maintenance cost, even in continuous 24-hour service. Minimum floor space and head room are required.

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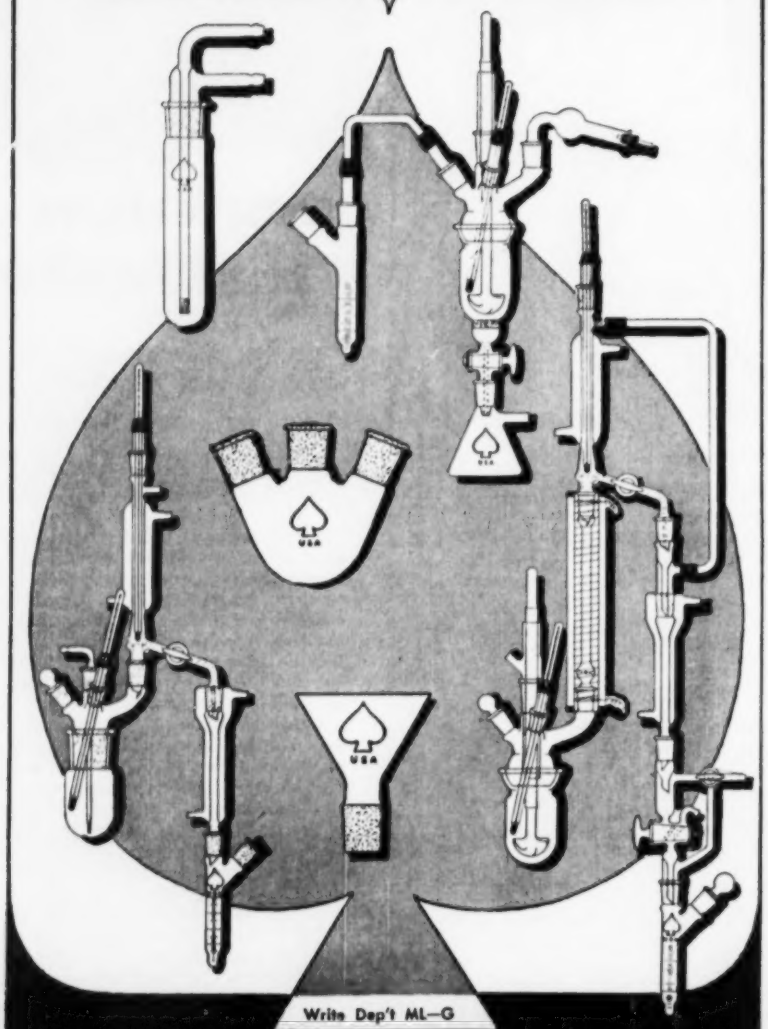

Write Dep't ML—G

Illustrated above are a few of the many assemblies and components listed in the new "Mini-Lab" Brochure—we will be pleased to send your copy immediately upon request.

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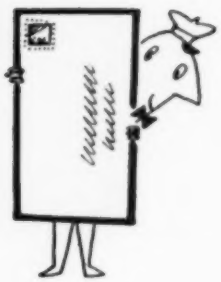
LETTERS TO THE EDITOR



Who Are You?

Occasionally we receive from members and subscribers unsigned letters which we cannot use. While we are perfectly willing on request, to protect anonymity by withholding the name of a correspondent, we must insist on the letter being signed so that we know the sentiments are genuine.—Editor.

Better Late Than Never

If I were not a procrastinator, you would have received a letter covering the excellent makeup and contents of the May issue of *Chemical Engineering Progress* two months ago. Now that the June and July issues have proven that the May number was not unique, I find that action cannot be further delayed and that multiple congratulations are in order.

These issues have been notable not only for the subject matter but also because they have been presented in an entertaining form and have been very easy to read, with the spice of the "Noted and Quoted" section rounding out a very satisfactory literary meal.

H. L. Bullock

New York, N. Y.

A Bouquet for Series

I was pleased to receive copies of "Transfer of Momentum in Jet of Air Issuing into a Tube" by Alexander, Comings, Grimmett, and White recently . . . reprinted from the Symposium Series No. 10. This looks very nice, and I am proud to have it in the Series.

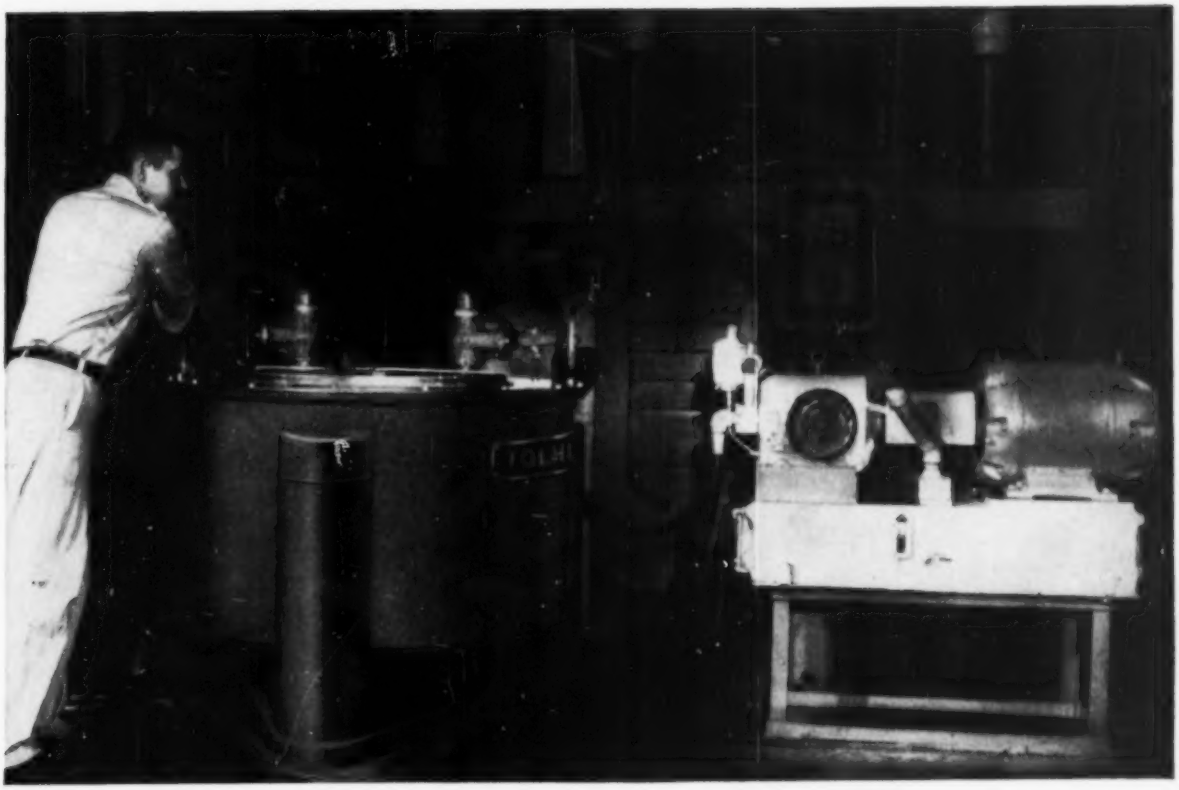
Lloyd G. Alexander

Oak Ridge National Laboratory
Oak Ridge, Tenn.

Are You "Young at Heart"?

I thoroughly enjoyed your editorial in the July *Chemical Engineering Progress*, entitled "The Young at Heart." It expresses to a remarkably large degree the way I feel about our profession. I think that every

(*Continued on page 6*)



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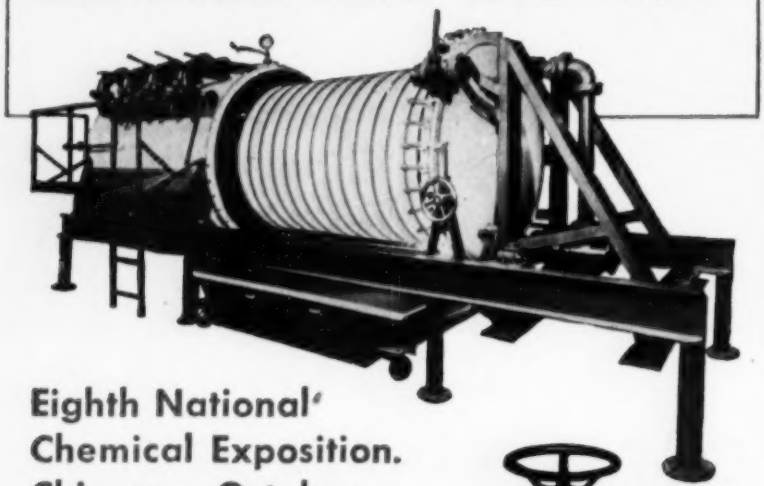
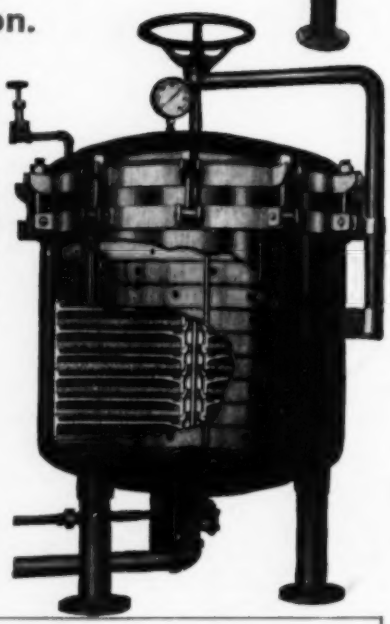


Eighth National Chemical Exposition. Chicago—October 12 to 15, 1954.



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LETTER TO THE EDITOR

(*Continued from page* 4)

chemical engineer, young and old, should read and think about this editorial.

I hope that we will be seeing more editorials of this type from your office. It is my opinion that we should be reminded of considerations beyond the day to day problems, at frequent intervals.

J. A. Patterson

Pittsburgh, Pa.

NOTED AND QUOTED

The New Frontiers

The last few years have seen advances in science and technology which amount almost to revolution in our life and world relations. If we maintain free minds, free spirits, and direct our steps aright, still other new horizons and new frontiers are open to us. New inventions and new applications of old knowledge will come to us daily.

These new frontiers give us other blessings. Not only do they expand our living but also they open new opportunities and new areas of adventure and enterprise. They open new vistas of beauty. They unfold the wonders of the atom and the heavens. Daily they prove the reality of an all-wise Supreme Giver of Law.

Former President Hoover at 80th Birthday Fete

And This No Fairy Tale!

Some engineer-economists foresee that by 1960—only 6 years from now—perhaps 10% of the *new* power plants on the drawing boards will have specifications for nuclear reactors, instead of coal, oil, or gas-fired boilers. These same experts say that by 1980 perhaps half of the new plants will use fissionable materials as fuels. However, I think these forecasts are too conservative.

Lewis L. Strauss
Speech to Veterans of Foreign Wars

The Horse-and-Buggy Stage

I have heard that there were people who asked Henry Ford, "Why do we need the automobile when we can get where we're going quicker on a horse?" Right now our objective is to advance our atomic power technology to the point where it can compete with the "horse" that is coal, gas and oil. But

(*Continued on page* 14)

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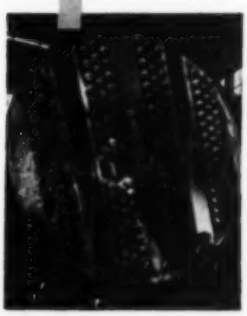

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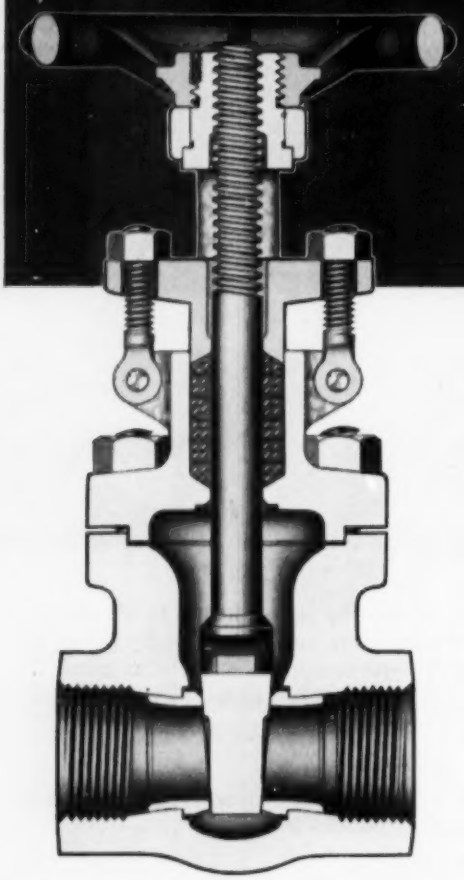

Screwed Ends—Union Bonnet or Bolted Bonnet

Socket-Welding Ends—Bolted Bonnet or Union Bonnet

Flanged Ends—Bolted Bonnet only

BOLTED BONNET OR UNION BONNET

In the cross-section of the bolted bonnet pattern above, you can see the rugged *big-valve* construction. Bolted bonnet valves available in sizes ½ to 2-inch—union bonnet valves in sizes ¼ to 2-inch.

Look no further for dependable steel valves in sizes up to 2-inch. Whether you prefer the union bonnet or bolted bonnet pattern, you get refinements usually found only in larger, more expensive valves.

For example, you get a compact, weight-saving structure of high-quality carbon steel. Smooth operation and positive closure of the solid wedge disc are assured by a T-head disc-stem connection and full-length machined guide ribs. There's also an unusually large stuffing box filled with high-grade packing, a leakproof bonnet joint with retained gasket, a husky stem with outside threads, and many others. To simplify maintenance, Crane design includes swinging gland eye-bolts—plus a wide yoke with liberal working space around the gland.

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There's versatility to these quality Crane steel valves, too. You can have your choice of trim to suit your service—Class X Trim (Exelloy body and body seat rings) for oil or oil vapor—Class XW Trim (Exelloy seat rings, disc of hardened stainless steel) for steam or water. Union bonnet valves also available with Class L Trim (18-8 Mo Alloy seats, disc, stem) for liquids and gases up to 750° F.

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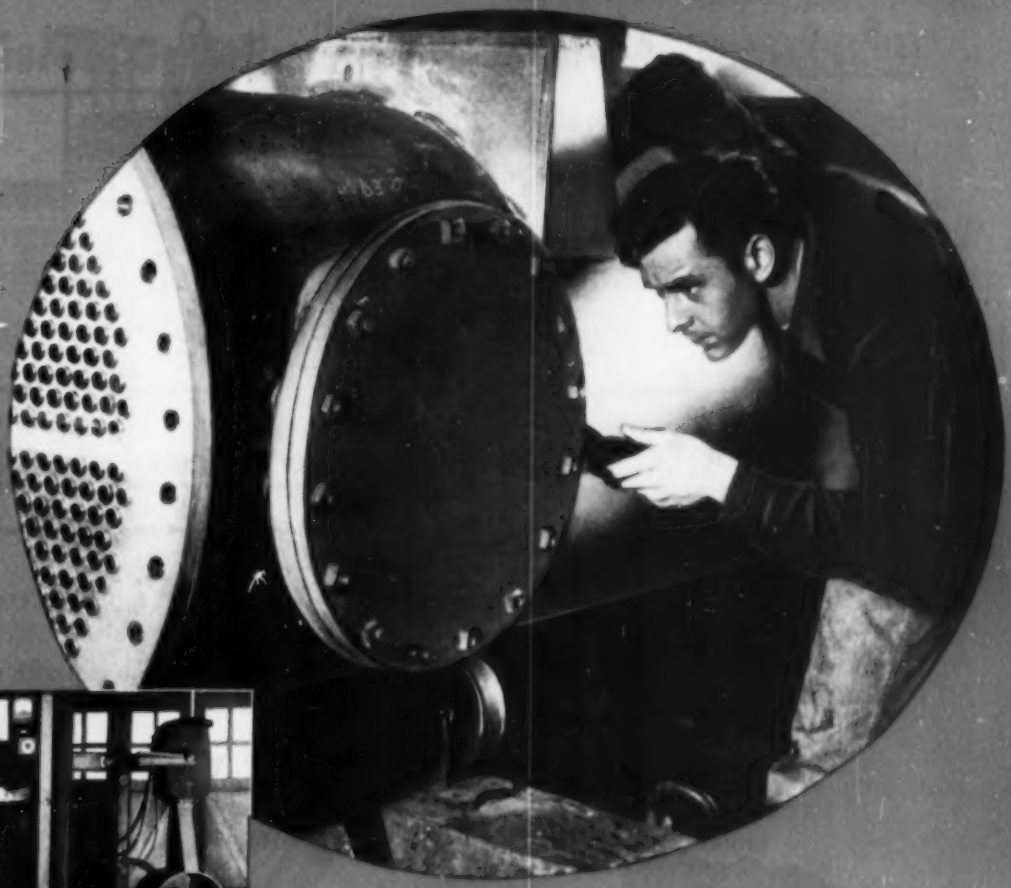

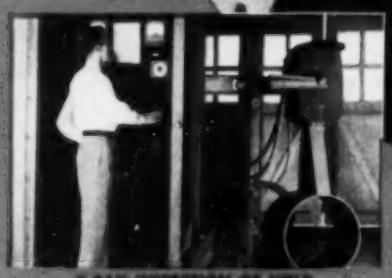

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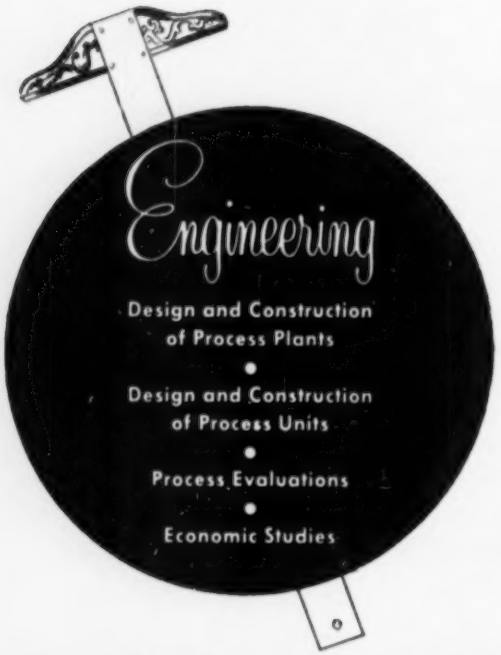

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SEATING LEVER
MALLEABLE IRON TRIM
TUFCLAD MOLDED FIBERGLASS ARMOR BONDED IN EPON RESIN
SOLID TEFLON WEDGE RINGS
LAPPED SEAT
Y-valves, angle valves, flush valves, safety valves, and plug cocks of Lapp Porcelain have standard bolt-circle flanges for easy connection to all piping and equipment
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PROCESS EQUIPMENT
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Chemical Proportioning Pumps

Long Before the "Squeeze Bottle"... Polyethylene Research Demanded High Pressure Autoclaves and Valves

The Polyethylene Research story published in Fortune early this year reports that great difficulty has been encountered in the manufacturing process. Ultrahigh processing pressures require new designs in valves, vessels, pumps, joints and pipes to handle the unprecedented conditions. These requirements challenge the best engineering brains of two continents. 30,000 p.s.i. plant valves as shown here will be used in the manufacture of polyethylene.

high pressure autoclaves, valves and fittings for laboratory and pilot plant are satisfying the demands of Research for operation in ranges of 0 to 100,000 p.s.i. It is primarily a matter of time and economics before commercial equipment will be available in the top operating range. The highly trained engineering staff at , the skilled craftsmen, modern production facilities and experience comprise a team you can depend upon to meet your research requirements. Write for your copy of Catalog 200.

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There is only one sure way to get what you pay for—to purchase a tower that will fulfill your performance specifications under test . . . in your plant. You can only obtain such a tower from a manufacturer whose engineering and research facilities are equal to the task.

Thirty years of research devoted exclusively to water cooling and a complete test plant enable Marley's cooling tower engineering staff (largest in the world) to predetermine tower performance scientifically and to verify it by actual test. That is why Marley not only invites but *urges* every customer to test his tower by any accepted test standard. Marley knows and positively guarantees that every tower it offers today will meet or exceed performance specification.

To help you determine this "difference" in cooling tower performance, Marley publishes helpful technical information to assist in testing all types of cooling towers. You can get this valuable information through Marley engineering representatives in all major cities, or by writing to the Technical Services Department of The Marley Company.

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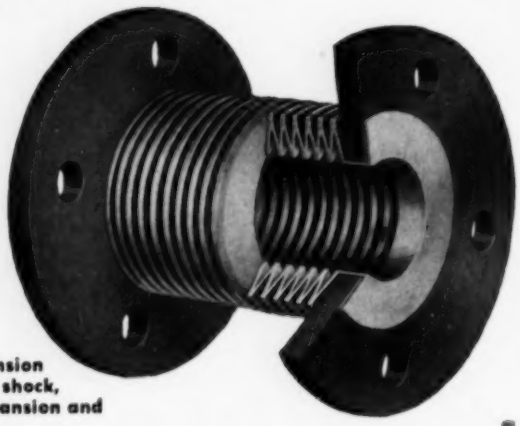

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NOTED AND QUOTED

(Continued from page 6)

that is just the beginning . . . there is more in the atom than that.

Gordon Dean, former Chairman
United States Atomic Energy Commission

War and Peace

While we must be prepared to meet the trial of war if war comes, we should gear our foreign and domestic policies toward the ultimate goal—the abolition of war from the face of the earth. That is what practically all mankind—all the great masses which populate the world—long and pray for. Therein lies the road, the only road, to universal peace and prosperity.

The voice of the people must be heeded.

The implacable guide must be faith in those unchangeable principles and ideals which give spiritual strength to our Constitution.

There must be reflected that degree of humility which recognizes the religious base upon which our nation was founded, with an indomitable determination to preserve it. The threat to freedom in peace is no less sinister than in war. Our country's future must not go by default.

Douglas MacArthur
"Revitalizing a Nation"

That Indispensable Man—The Scientist!

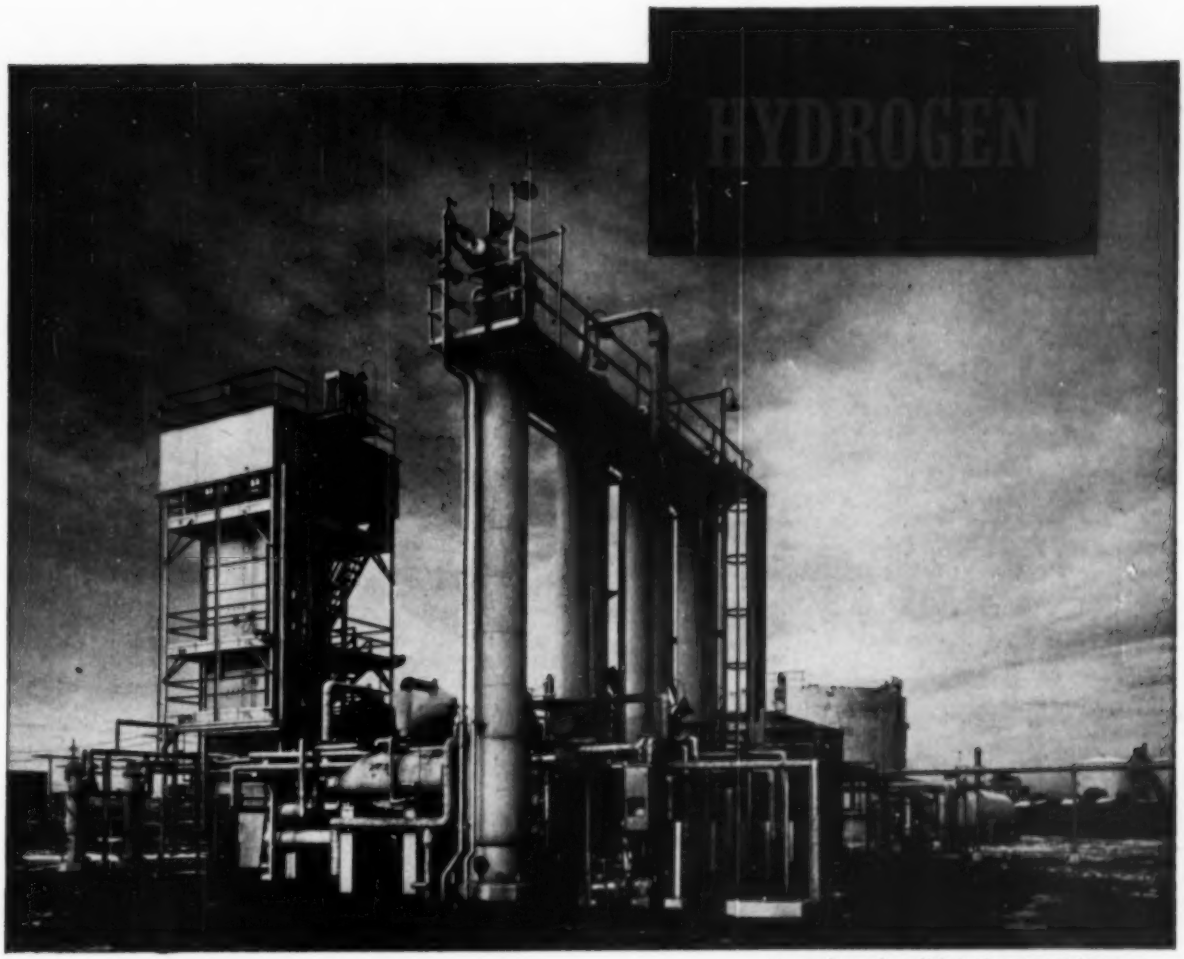
Please do not believe, because I defend the humanities, that I attack the sciences. Without the scientists we would be lost, indeed. Their positive contributions are indispensable and beyond counting. It is not their fault if the world has become a security risk.

John Mason Brown
Commencement Address, Hofstra College
Saturday Review

Emergency Measure

In World War I, President Wilson appointed a consulting board to assist the Navy. Thomas Edison was the chairman; his appointment was widely acclaimed by the press—the best brains would now be available for the application of science to naval problems. The solitary physicist on the board owed his appointment to the fact that Edison in choosing his fellow board members had said to the President, "We might have one mathematical fellow in case we have to calculate something out."

James B. Conant
in "Modern Science and Modern Man"



At new Chicago plant of The Southern Cotton Oil Company

Hygirtol plant produces high purity hydrogen continuously

THIS GIRDLER HYGIRTOL* PLANT provides a continuous supply of hydrogen of a purity exceeding 99.8%. Operation of the plant is practically automatic, clean, safe, instrument-controlled, and its output can be varied readily from 50% to 110% of rated capacity.

Girdler designs and builds complete process plants such as this, assuming responsibility for all phases of planning and construction. This assures coordination and sound results. For complete information, call the nearest Girdler office.

*HYGIRTOL—Trade Mark of The Girdler Company

GIRDLER DESIGNS processes and plants
GIRDLER BUILDS processing plants
GIRDLER MANUFACTURES processing apparatus

GAS PROCESSES DIVISION:

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Hydrogen Cyanide Plants
Synthesis Gas Plants
Carbon Dioxide Plants
Gas Purification Plants
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Sulphur Plants
Acetylene Plants
Ammonia Plants
Ammonium Nitrate Plants
Hydrogen Chloride Plants
Catalysts and Activated Carbon

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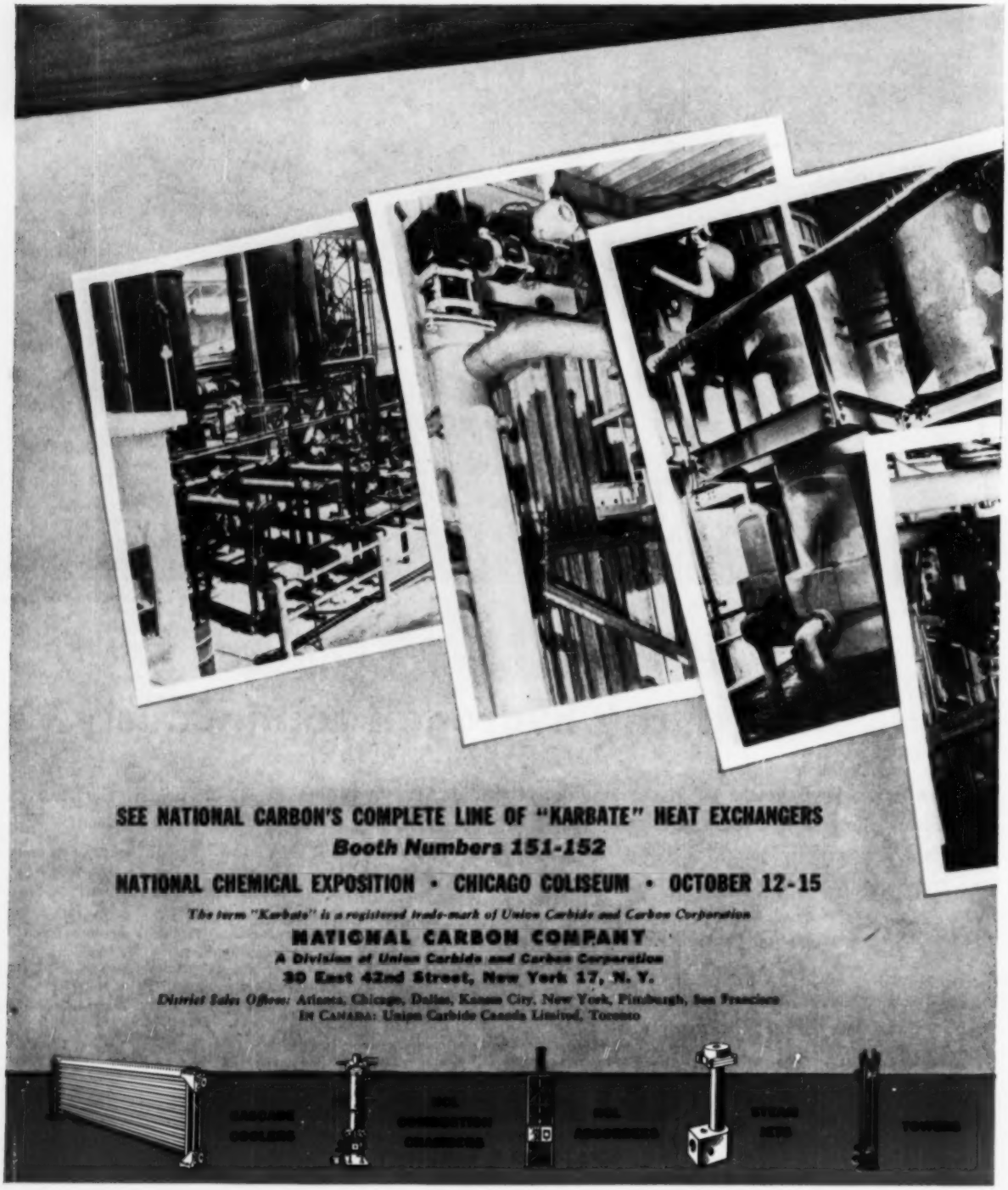
GAS PROCESSES DIVISION: New York, Tulsa, San Francisco
In Canada: Girdler Corporation of Canada Limited, Toronto

THEY'VE CUT COSTS

IMPERVIOUS GRAPHITE



SEE NATIONAL CARBON'S COMPLETE LINE OF "KARBATE" HEAT EXCHANGERS

Booth Numbers 151-152

NATIONAL CHEMICAL EXPOSITION • CHICAGO COLISEUM • OCTOBER 12-15

The term "Karbate" is a registered trade-mark of Union Carbide and Carbon Corporation

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District Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

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HEAT EXCHANGERS

YOU CAN, TOO – HERE'S WHY:

Economy – all the way down the line – keynotes NATIONAL CARBON'S standardization of "Karbate" impervious graphite shell-and-tube heat-exchangers, from the smaller, stock items to those providing as much as 2300 square feet of heat-transfer surface per unit.

COST LESS TO BUY: Producing and stocking proved designs in quantity, National Carbon offers "Karbate" shell-and-tube heat-exchangers at low first-costs and with even greater flexibility of application. For example, "Karbate" Series 90A and Series 310A heat-exchangers provide from 18 to 162 square feet of surface area in tube lengths from 6 to 16 feet, with a choice of 1, 3 or 5-pass tube-side arrangements, *all from stock*. Similarly, *stock* "Karbate" impervious graphite standardized tube-bundles and covers are used by leading heat-exchanger manufacturers in units of their own design, which offer a range of tube-surface areas from 80 to 2300 square feet in tube lengths to 16 feet. Shell-and-tube side-pass arrangements are virtually unlimited.

COST LESS TO USE: "Karbate" shell-and-tube heat-exchangers combine the complete corrosion resistance, high thermal conductivity, and immunity to thermal shock of "Karbate" impervious graphite with *designs* that are simple, rugged and versatile in application. The result—lowered operating costs and reduced maintenance, plus the *adaptability* so desirable in today's modern plant.

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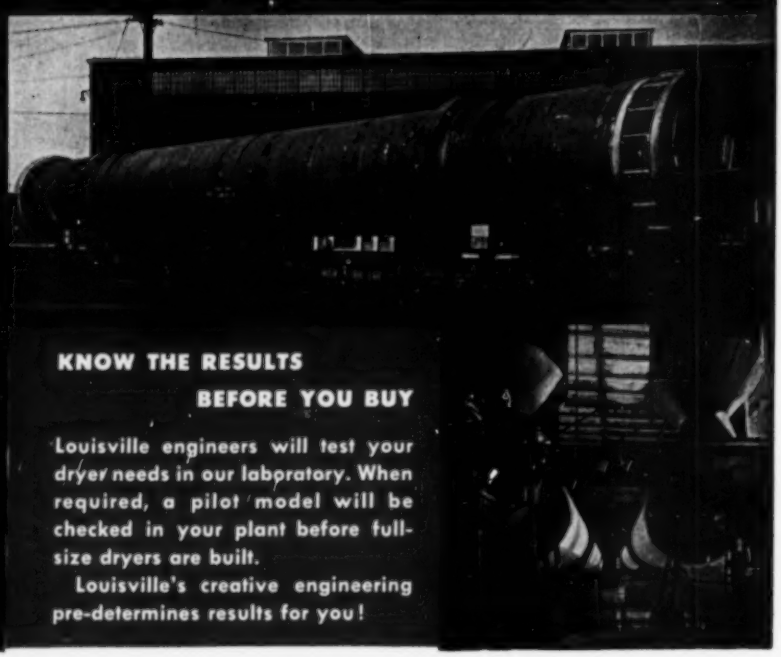
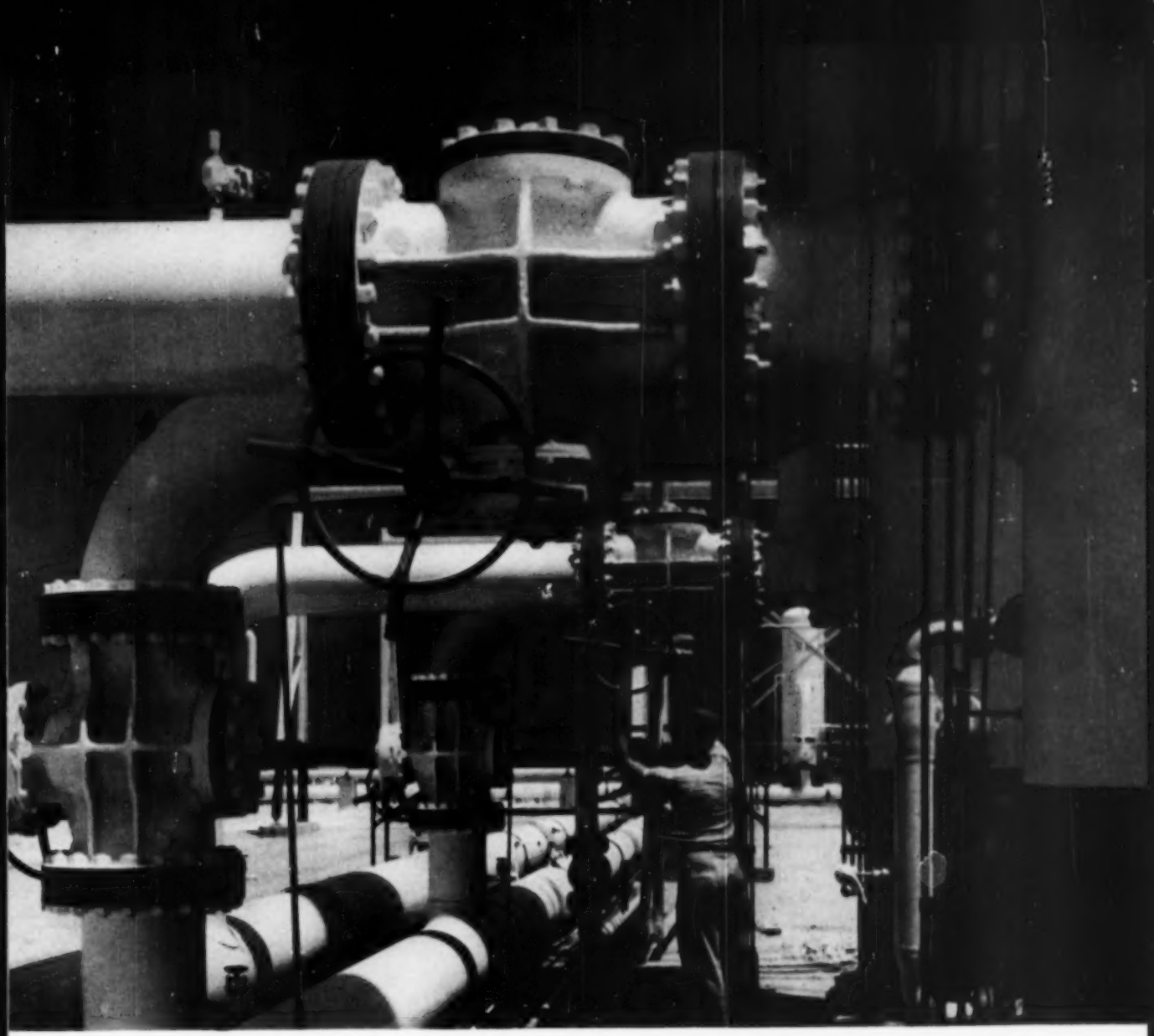


KNOW THE RESULTS BEFORE YOU BUY

Louisville engineers will test your dryer needs in our labpratory. When required, a pilot model will be checked in your plant before full-size dryers are built.

Louisville's creative engineering pre-determines results for you!



OPEN . . . CLOSE . . . EASY . . . WORK . . . TIGHT

Certainly . . . no question the valve will operate when it's needed if it's a Rockwell-Nordstrom. It isn't necessary to experiment with valves—Rockwell has done the research for you. The originator of lubricant-sealed valves, with more valves in more different services than any manufacturer, Rockwell can fit the proper valves and lubricants to your application.

There is no substitute for Rockwell-Nordstrom experience—use it to save money on valves. *Rockwell Manufacturing Company, Pittsburgh 8, Pennsylvania.*

THREE WAYS THE NORDSTROM LUBRICANT WORKS

Lubricant surrounds each valve part with a vapor tight pressurized seal. **Nordstrom valves stay tight.**

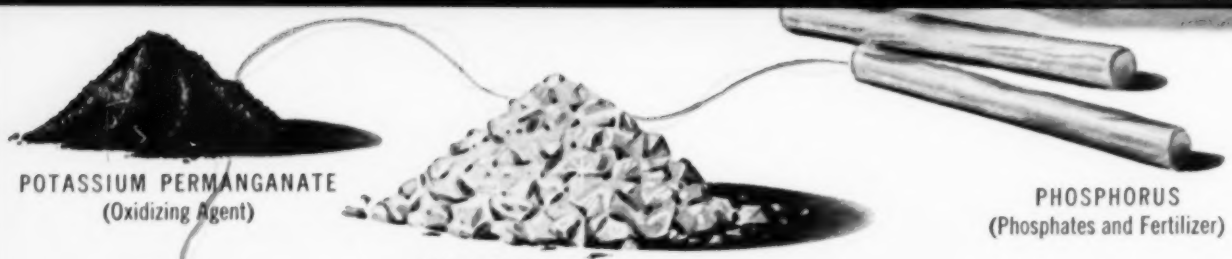
Lubricant acts as hydraulic jack—a fast quarter-turn to open or close. **Nordstrom valves operate quickly.**

Lubricant coats the plug for sliding action—no wear-producing wedging. **Nordstrom valves operate easily.**

Rockwell Built

NORDSTROM VALVES

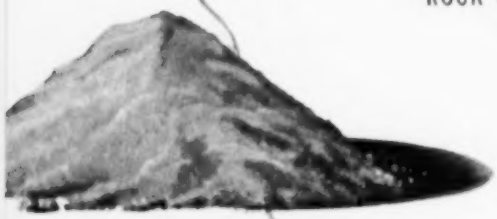
Lubricant Sealed for Positive Shut Off



POTASSIUM PERMANGANATE
(Oxidizing Agent)

ROCK CRYSTAL SALT
(Brine)

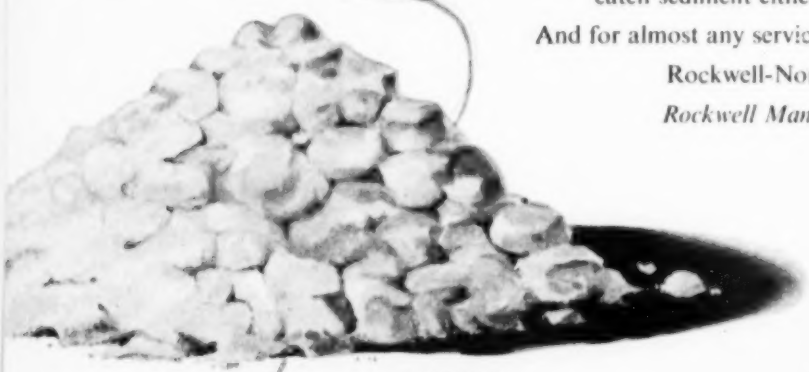
PHOSPHORUS
(Phosphates and Fertilizer)



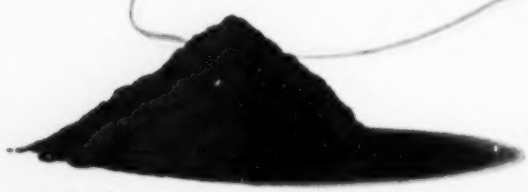
CLAY SLIP
(Ceramics)

POTASSIUM DICHROMATE
(Oxidizing Agent)

BAUXITE
(Aluminum)



SULPHUR



FERRIC OXIDE
(Paints)

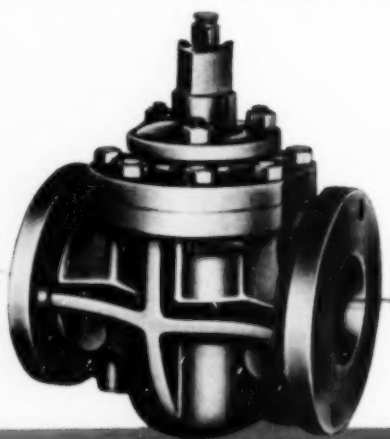
HOW TO END SLURRY WORRY

Slurries and entrained solids eat the heart right out of many types of valves—and incidentally eat up process industry profits at the same time.

The point is that all solids are essentially abrasive, gritty, erosive. They tend to pit ordinary valve seats, or channel leakage paths, and replacement costs mount.

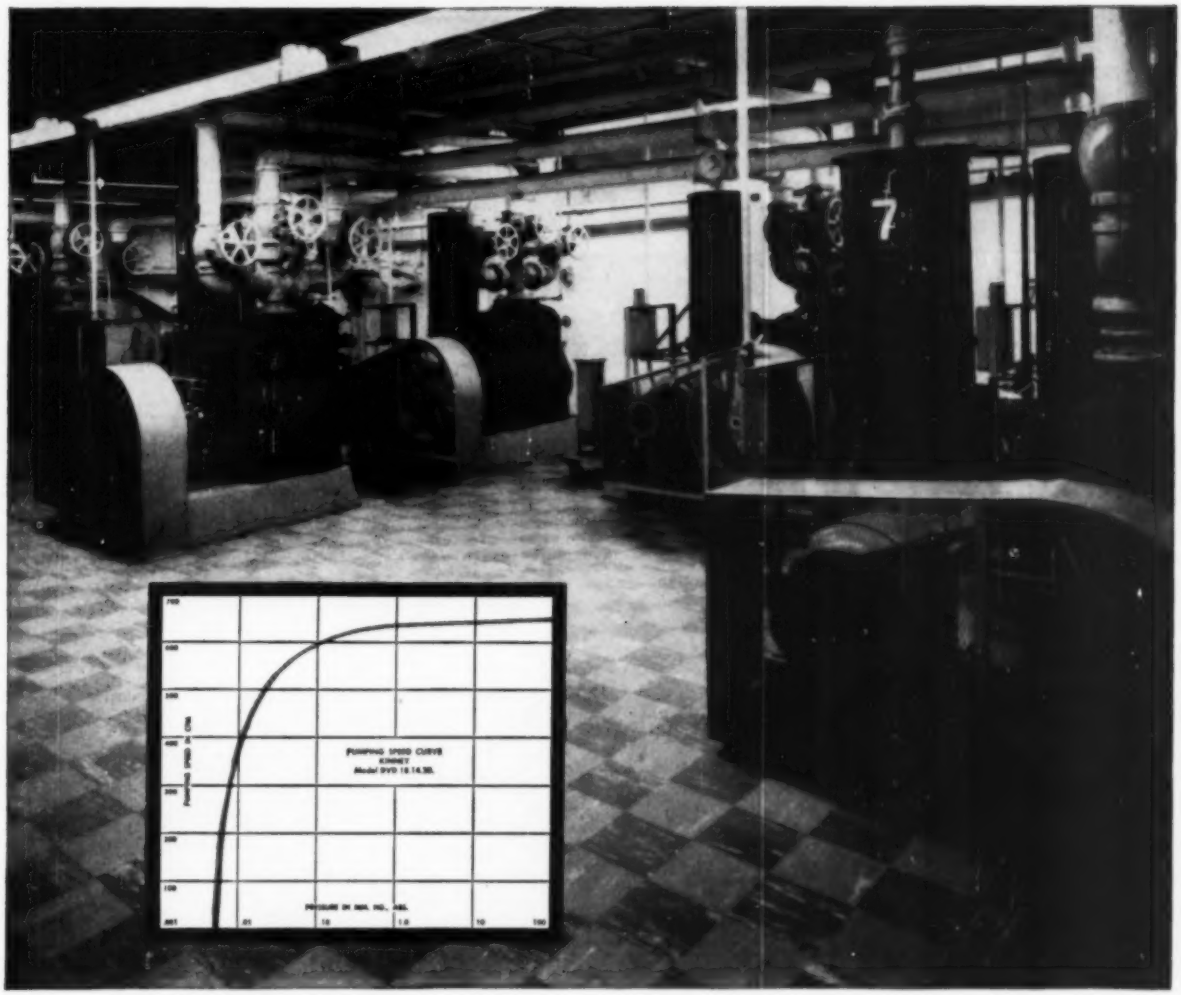
But not necessarily. Rockwell-Nordstrom valves have been proven to outlast other valves in many difficult services, like those shown here.

The reason is this: there's no exposed seat to wear away; instead there's a pressure seal of lubricant, and the essential points of closure are out of the path of flow. There are no valve body pockets to catch sediment either—just smooth, straight-through flow. And for almost any service, there's a correct and tested genuine Rockwell-Nordstrom lubricant. Get the facts from *Rockwell Manufacturing Company, Pittsburgh 8, Pa.*



Nordstrom Valves

Another Quality ROCKWELL Product



They use Fast Vacuum

In the lamp and tube manufacturing business, you will find many "house vacuum" systems like this . . . built around super-dependable Kinney High Vacuum Pumps. This particular room, in the plant of a leading manufacturer of electronic and electrical equipment, contains seven Kinney Model DVD 18.14.20 Pumps with a combined vacuum potential of 5,000 cubic feet per minute. This is the heart of the vacuum exhausting process . . . the key to fast pump-down and fast production.

Whatever your vacuum problem — whether it's a laboratory job requiring a 2 CFM pump or a full scale production problem like this — there's a Kinney Pump to fit your needs. Kinney district offices are staffed with competent vacuum engineers, ready to help you get the right vacuum pump for each application.

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. . . for small volume capacity at low or high pressures

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- *supplying power for molding and belt presses*
- *testing tubing, valves or pressure vessels*
- *ideal for laboratory as well as production use*
- *and for many other applications requiring small volume capacity at low or high pressures.*

Special muffler design provides quiet operation.

Aldrich Air-Driven Hydraulic Pumps are available in low and high pressure models, single or double-acting. Plunger diameters for the low pressure range are 1¼" to 3". High pressure range, ½" to 1⅛". Double-acting units provide minimum pressure fluctuations in addition to greater volumes.

Write for new Data Sheet 36 for complete details.

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- FIRED PETROLEUM FURNACES
- FLUID TO FLUE GAS HEATERS
- GAS (NATURAL AND MF'D.) HEATERS
- GAS TURBINE RECUPERATORS
- INERT GAS GENERATORS
- INERT GAS COOLERS
- MOLTEN SALT HEATERS
- ETHYLENE FURNACES
- REBOILERS—CHEMICAL PROCESS
- SODIUM VAPOR GENERATORS
- STEAM GENERATORS
- TEST FACILITIES—JET ENGINE PARTS
- WASTE HEAT STEAM GENERATORS
- WASTE HEAT AIR HEATERS
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1800°C	INTERNAL COMBUSTION ENGINE
1700°C	DIRECT FIRED HEATERS (FLAME)
1300°C	KILNS
1250°C	CERMETS (HIGH STRESS USE)
1200°C	ACETYLENE (WULF THERMAL PROCESS)
1100°C	COKE OVEN
1093°C	COMPRESSED AIR
925°C	GAS TURBINE (GASES)
852°C	$NaCO_3$ (MELTS)
845°C	HCl FROM SALT
815°C	COMPRESSED AIR
810°C	FUSED METALS FOR HEAT TRANSFER
810°C	GAS TURBINE (METAL)
800°C	IRON (RED HOT)
800°C	NaCl (MELTS)
770°C	KCl (MELTS)
750°C	HNO_3 FROM NH_3
700°C	THERMAL CRACKING (PETROLEUM)
648°C	COMPRESSED AIR
600°C	METAL SALTS FOR HEAT TRANSFER
550°C	NH_3 BY HABER BOSCH PROCESS
538°C	PETROLEUM OIL FOR HEAT TRANSFER
537°C	ETHYLENE (FURNACE)
537°C	CAT-REFORMING OF GAS OIL
537°C	COMPRESSED AIR
500°C	H_2SO_4 BY CONTACT PROCESS
426°C	COMPRESSED AIR
397°C	POTASSIUM DICHROMATE MELTS
375°C	CRITICAL POINT OF WATER
365°C	DOWTHERM (100 #/IN.² ABS.)
350°C	COMPRESSED AIR
327°C	LEAD (MELTS)
315°C	BUTADIENE FROM ETHYL ALCOHOL
271°C	DOWTHERM (50 #/IN.² ABS.)
240°C	DOWTHERM (10 #/IN.² ABS.)
229°C	STEAM (400 #/IN.² ABS.)
193°C	STEAM (200 #/IN.² ABS.)
164°C	STEAM (100 #/IN.² ABS.)
100°C	WATER BOILS
79°C	ALCOHOL BOILS
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VACUUM PUMP MAINTENANCE COSTS and BETTER VACUUM . . .
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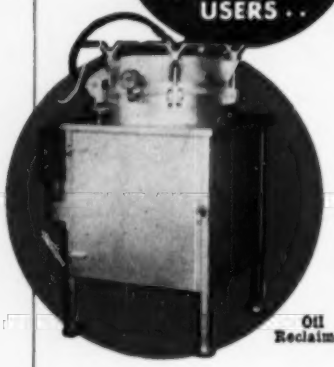
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A simple, economical and efficient method of restoring contaminated lubricating and sealing oil to the full value of NEW OIL. The HILCO will produce and maintain oil free of solids, gums, water and gases in a continuous, all-electric, automatic operation.
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Marginal Notes

For the Practical Idealist

Shirt-Sleeve Diplomacy. Point 4 in Action. Jonathan B. Bingham. The John Day Co., New York (1954), 303 pp. $4.00.

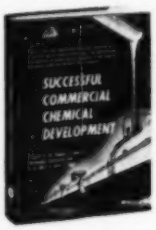
Bingham, the author of this book, was probably in the best position of any man to see the workings of the Point 4 program. For a year and a half he was Deputy Administrator of the Technical Cooperation Administration, and for another five months he was Acting Administrator. Point 4's inception was the Truman Inaugural Address in 1949, and by 1954 the U.S.A. was spending more than 300 million dollars a year to bring technical and scientific aid to those nations of the world who could use it and who would welcome it.

Bingham tells a fascinating tale, and no engineer can read this book without experiencing a tremendous urge to pitch in and help. The ingredients of engineering miracles are all there—men, money, materials, and most of all, need. The examples that Bingham gives in the book are thrilling; how a Point 4 agricultural expert helped Indian farmers in Etawah double wheat yields through better seed and plows; how Liberian natives were taught to grow rice in swamps during the "dry hungry season," and how the same American agricultural expert sold cacao, coffee, and oil palm seeds for a token two cents to the inland Liberians, taught them how to plant and care for the crops, and had the satisfaction of seeing the cash income of the natives rise from five to twenty-five dollars annually—not much by our standards but a great improvement for those involved.

American teams have stopped locusts in Iran, rinderpest in India, potato blight in Ecuador, and in Peru they demonstrated so well the value of chemical pesticides that "Dupont Company's manager in Lima showed . . . a new mixing plant for pesticides and was frank to admit that S.C.I.P.A.'s (U.S.-Peruvian Agricultural Service) operations were responsible for its construction."

These examples are all agricultural, but many more could be quoted from the fields of engineering, health, and education. It is a wonderful book to read, guaranteed to overcome the usual inferiority complex most Americans have when thinking about our diplomatic record. Point 4 may not work, may not bring peace, and may make those we help hate us. But whether it does or not, the program as described by Bingham is certainly a warmhearted humanitarian act of brotherhood.

F.J.V.A.

Available Now . . .
SUCCESSFUL COMMERCIAL CHEMICAL DEVELOPMENT
Prepared by the Commercial Chemical Development Association, with B. M. CORLEY of Armour and Company, as Editor-in-Chief


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More than 100 leaders of the American Chemical Industry Contributed to This Book!
Each chapter represents the thinking of many people; men who forecast demands for both existing and new products, men skilled in testing product acceptability; men working on the practical meanings of economic trends in both raw materials and finished goods. Their articles are arranged so that you get a clear, organized, step-by-step and stage-by-stage picture of the entire process of the successful development of new products in the chemical field.
They give you a wealth of sound advice, based on actual experience, which will help you to
Appraise a new product idea
Understand, fully and in detail, the many factors which determine the desirability of a proposed new chemical product
Utilize manpower most efficiently and effectively in developing and producing such new products
Avoid waste and loss in the expenditures necessary for development
Increase profits on each product
In addition to the actual technique of developing and producing new chemicals, this work covers: Sales; Advertising and Merchandising; Trade Mark; Patent and other legal phases; Competing Products; Labeling; Packaging and Shipping; and many other factors.
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MARGINAL NOTES

(Continued from preceding page)

Scientific and General Information

Vegetable Fats and Oils. E. W. Eckey, with a chapter by Lawrence P. Miller, ACS Monograph No. 123, Reinhold Publishing Corp., New York (1954), 836 pp. $16.50.

Reviewed by Martin D. Reinish, Colgate-Palmolive Co., Jersey City, N. Y.

This valuable book succeeds the out-of-print ACS Monograph No. 58 of the same title by G. S. Jamieson. However, it is newly written in its entirety and differs in many ways from its predecessor. Though retaining the principal feature of the original volume, a section describing nearly all of the vegetable fats and oils about which much scientific information has been published, it also contains chapters with general information on fats and oils. These include chemical composition, physical properties, chemical properties and reactions, analytical methods, biochemical aspects, and genesis of fats and oils in plants.

In the descriptive section the fats and oils are grouped according to the botanical classification of the oil-bearing plant. This is in contrast to the usual method of classification as nondrying, semidrying, and drying oils and allows convenient comparison of oils of related plants. All oils mentioned are also listed in the index. Under each of the individual oils a description of the plant is given followed by chemical constants and composition of the fatty acids in the oil. For the commercially important oils considerably more information is given. This includes data on occurrence of the plant, production figures, and methods used to obtain the oil from the plant. There is also some mention of further treatment of the oils for improving color, odor, or physical properties.

The chapter on physical properties, in addition to describing the properties, discusses briefly analytical methods and separation procedures which make use of differences in physical properties. Likewise, the chapter on chemical properties and reactions mentions practical applications of the various reactions, including a fairly detailed treatment of hydrolysis and hydrogenation.

For the chemical engineer engaged in the production, processing, or use of vegetable oils this book is a valuable source of information. However, it should be emphasized that no attempt is made to cover fully the milling, processing, and utilization of the oils, and additional sources are required for this in-

(Continued on page 32)

HERE'S THE *New* RUPTURE DISC FOR BS&B SAFETY HEADS...

...ESPECIALLY DESIGNED FOR USE IN LOW PRESSURE APPLICATIONS UNDER SEVERE CORROSIVE CONDITIONS!

For many years the problem of producing a low pressure rupture disc that could withstand prolonged exposure to severe corrosive conditions was a perplexing one. Yet, it was a problem that *had* to be solved, particularly for the Process Industries.

Therefore, it was only natural that BS&B — originator of the Safety Head — should come up with the right answer in the form of a flat type rupture disc whose bursting pressure is controlled by a top metal section, isolated from the corrosive contents of the protected vessel by a sealing membrane of Teflon or Kel-F.

If back pressure is not anticipated, the bottom metal section of the disc is cut open to full relieving capacity (Model 1A). However, if a vacuum support is needed, the bottom metal section is constructed similar to the top section to serve as a vacuum support (Model 1B). Top and bottom sections are spot welded together to give a single compact unit.

Disc Models 1A and 1B are constructed of corrosion-resistant metals such as Inconel, stainless steel, nickel, Hastelloy B and Monel. Either model is available in 2", 3", 4", 6", 8" and 10" sizes. Pressure ratings are from 8 to 100 lbs. Close design tolerances are an inherent feature of this type disc.

If you have a pressure relief problem which you have not been able to solve satisfactorily with the regular pre-bulged type of disc or other types of relief devices, try the new BS&B Model 1A or 1B disc. It fits any standard size BS&B Safety Head flanges you may now have in service. Also available in a complete assembly consisting of inlet and outlet flanges, rupture disc, studs and nuts.

Your BS&B Man will be glad to give you details . . or you may write for descriptive literature and prices.

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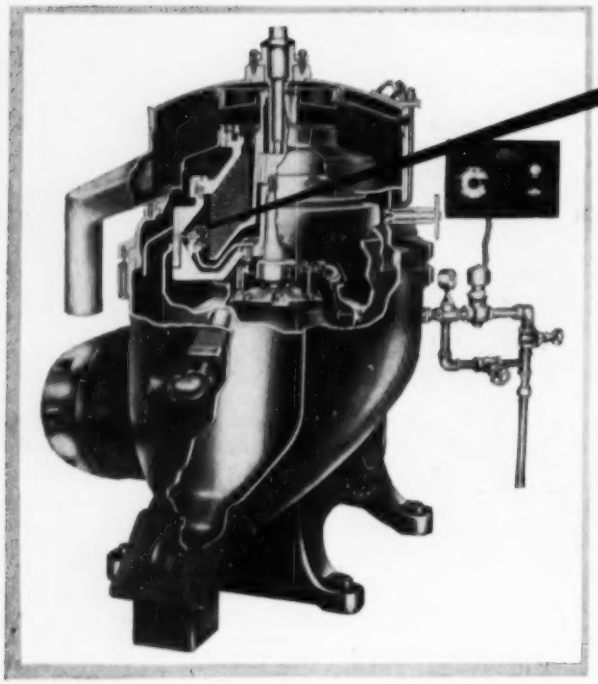
SHARPLES DV-2

the centrifuge with external control of solids consistency



Merely by setting two externally mounted timers, the discharge valves of the Sharples DV-2 may be controlled as desired—both for frequency and duration of valve opening. As a result, this high speed disc type centrifuge provides great flexibility for the control of the consistency of the solids which are discharged continuously—flexibility that means process control.

In many applications a firmer cake can be built up by lengthening the time between valve openings, with attendant drier discharge. By adjusting the duration of valve opening, contamination of solids by liquids can be minimized, or valuable liquids may be withheld from the solids discharge. By controlling both frequency and duration of valve opening, desired concentration can be accomplished.

The ten externally controlled valves in the DV-2 clarifier or separator, are operated by the admission of water or other operating liquor through a completely closed system, separate from the material being centrifuged. The large diameter valve ports are of the non-clogging removable type; wearing parts are selected for maximum abrasion and corrosion resistance.

It will pay you to investigate the advantages of the Sharples DV-2—the nozzle centrifuge with positive, externally controlled solids discharge valves.

Do you need accurate, rapid particle size distribution analyses? Ask for Bulletin 101 The Sharples Micromeregraph

The Sharples Corporation will be glad to answer questions specific to your problem; Bulletin 1243 will be sent upon request

SHARPLES

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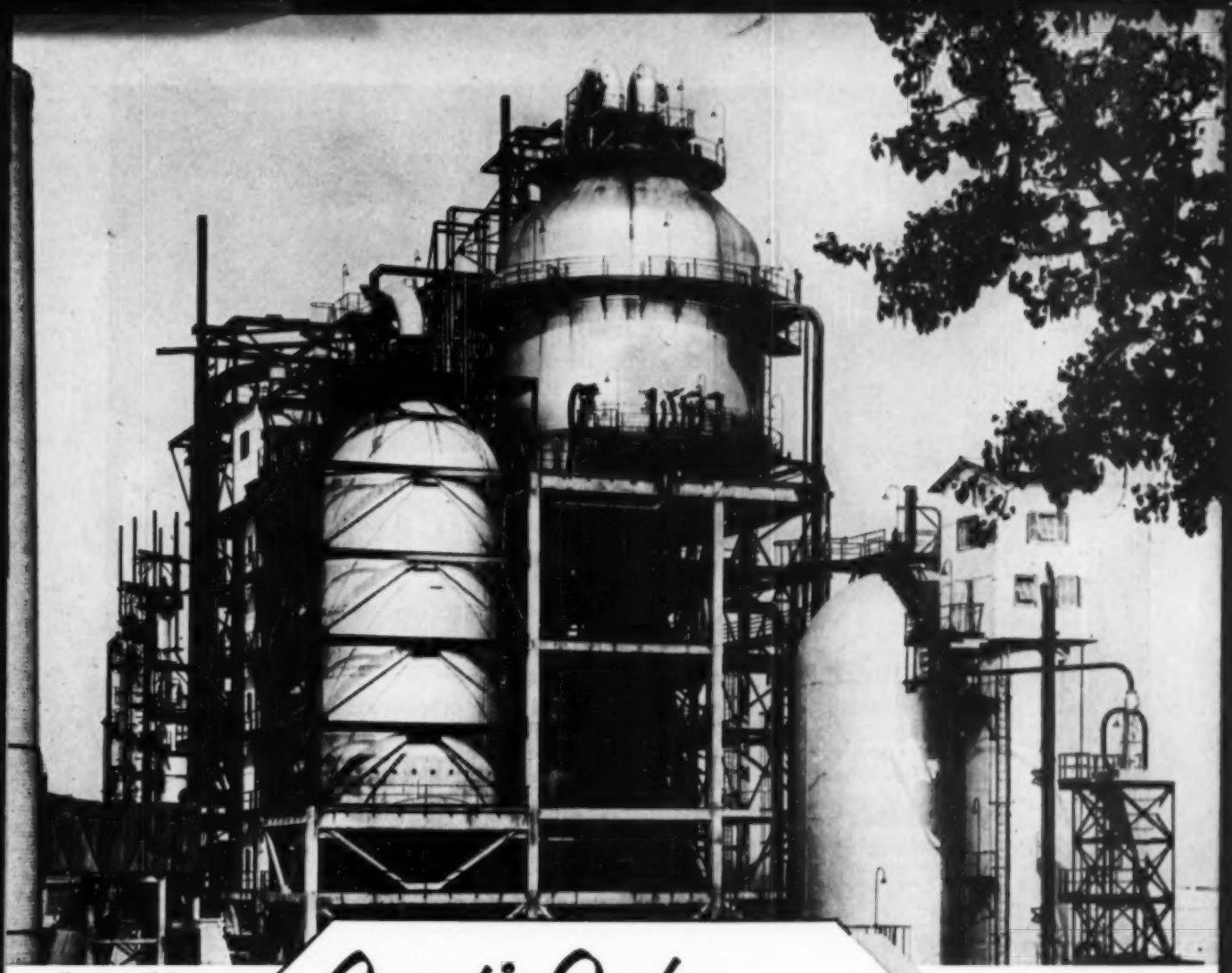

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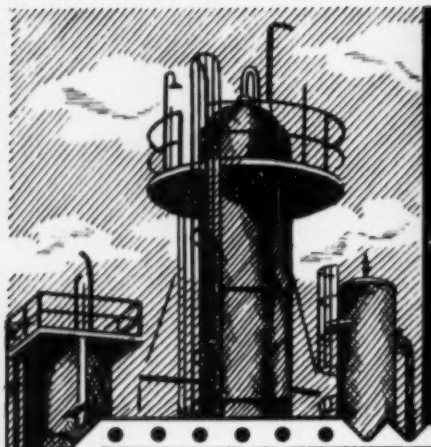

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REDUCE harmful air pollution
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CASE STUDY
No. 1004

VACUUM TOWER CAPACITY INCREASED 35% WITH YORKMESH DEMISTER

OBJECTIVE:

To increase feed rates from 20,000 bbl. per day to 26,000 bbl. per day without affecting gas-oil overhead quality.

PROBLEM:

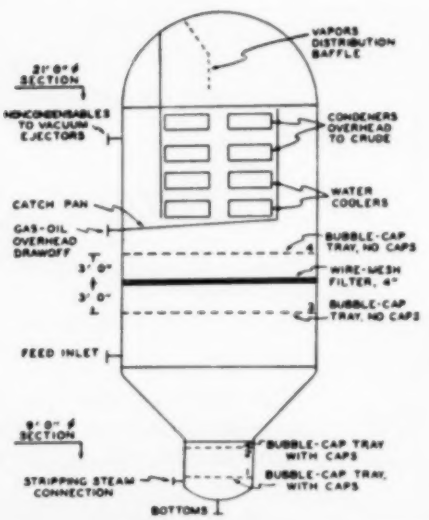
Entrainment of asphalt in the gas-oil vapors, at the high vapor velocities which were required, had made it impossible to produce a gas-oil overhead suitable for cracking feed stock.

SOLUTION:

Two wiremesh demister pads, each 2" thick and fabricated from type 304 stainless steel, placed at right angles to each other and wired together for a total thickness of 4", were installed in place of one of the original bubble trays.

RESULTS:

The use of these wiremesh demister pads increased the feed capacity 35%, and not only maintained, but actually improved the gas-oil quality.



Note To get the facts behind this 35% tower capacity increase write for Case Study No. 1004.

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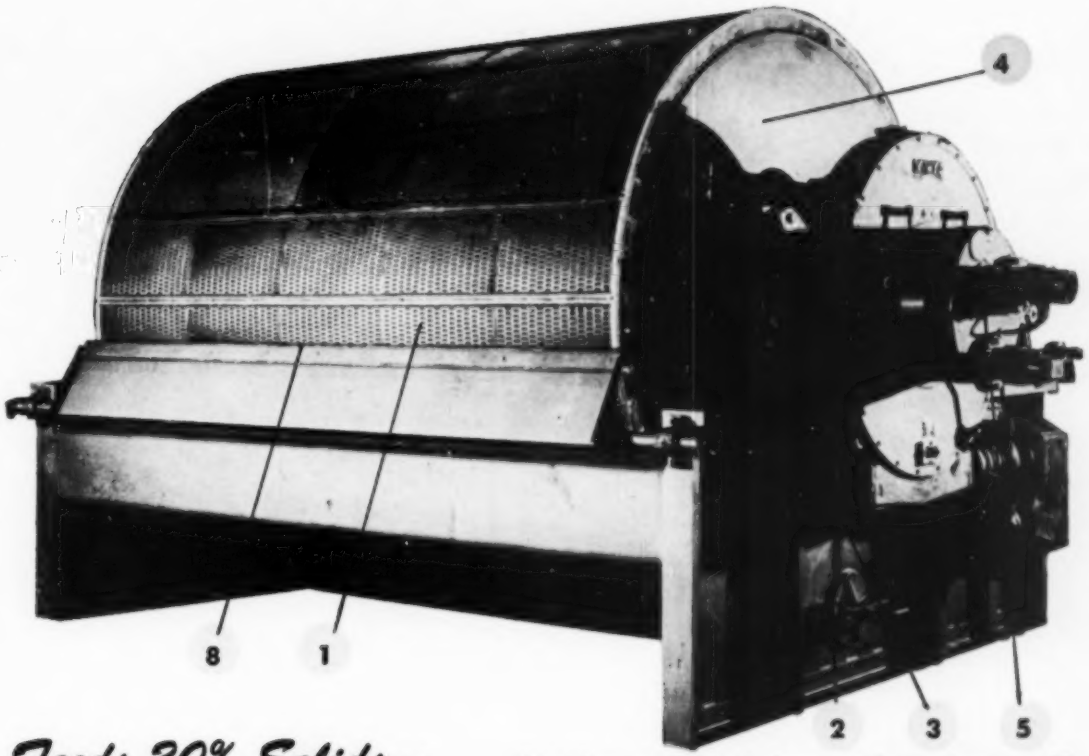

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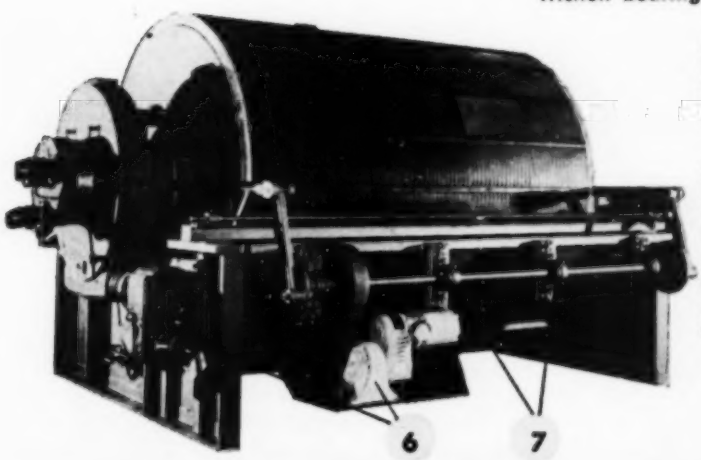

In operation a dutch weave wire cloth is caulked in the grooves and the snap blow lifts the cake from the panel away from the drum surface so that the (8) rubber tipped blade never touches the drum.

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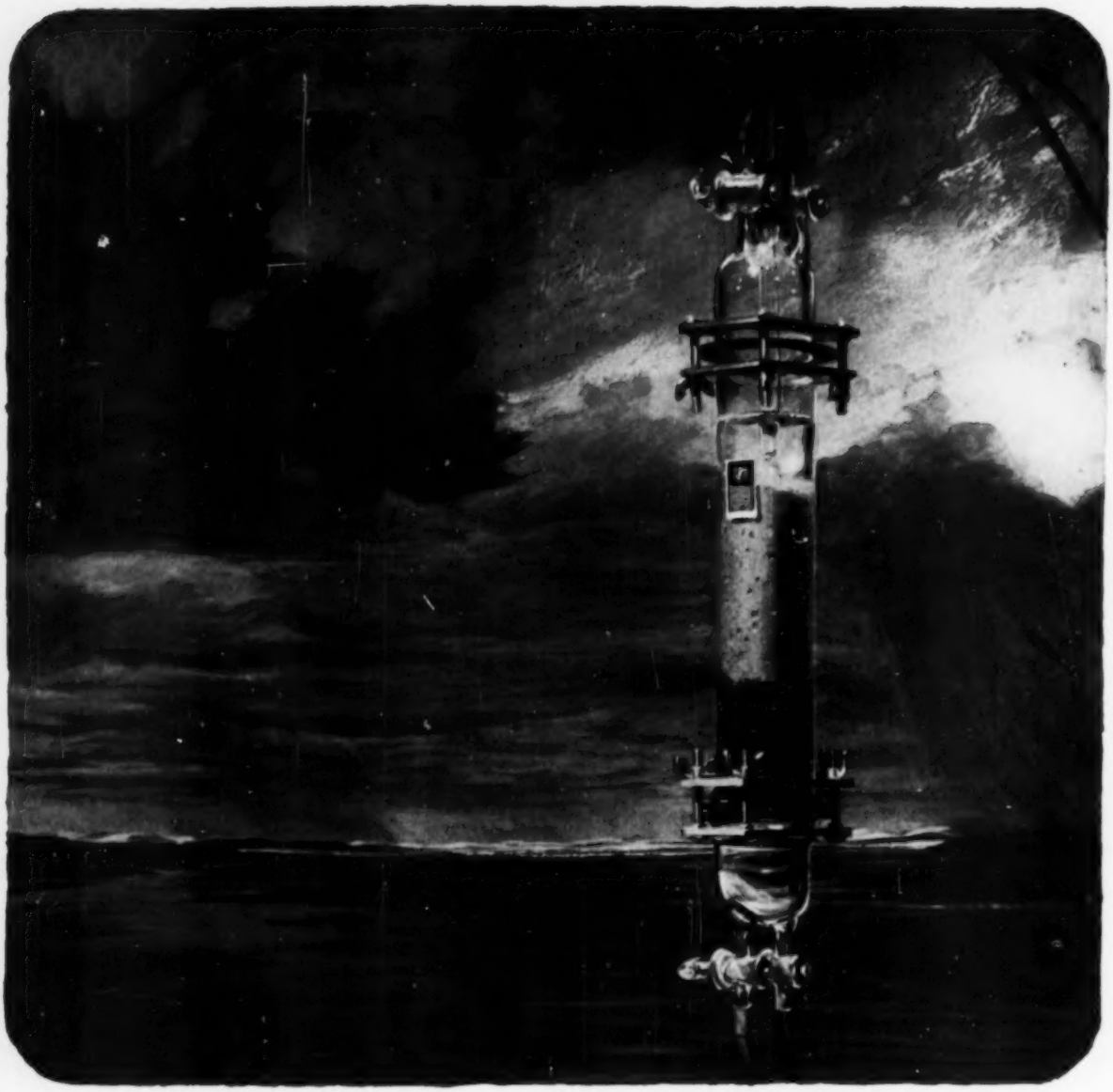

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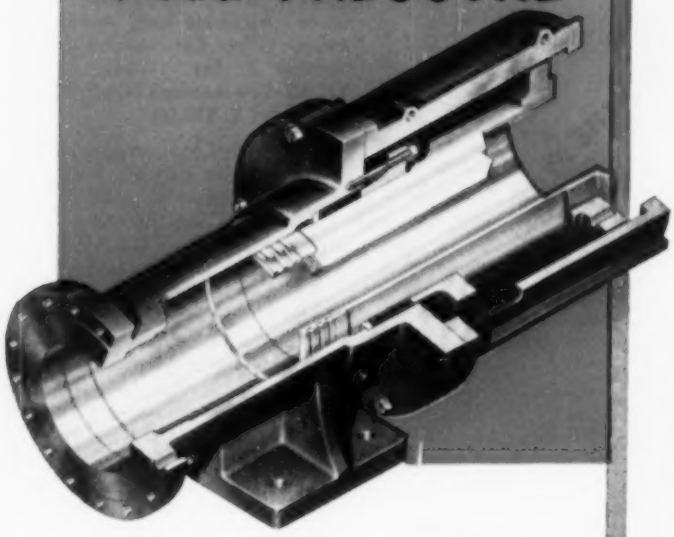
ADSCO EXPANSION JOINTS...

UNPACKED AT FULL PRESSURE



▶ ADSCO piston-ring expansion joints can be serviced . . . in fact, unpacked and repacked . . . under full line pressure. There is no interruption of service, no down-time for repacking, because the job is done under normal working conditions.

▶ Yet this isn't the only great feature of this high-quality joint. Slip is completely guided . . . split external guide permits smaller manholes . . . limit stops prevent over-travel of slip . . . polished surface cannot be scored because slip is in contact with packing only . . . misalignment is prevented by both internal and external guiding. ADSCO piston-ring expansion joints are available in a full range of sizes, with 4", 8", or 12" traverse per slip, for pressures to 400 psi and greater and for temperatures to 800F and higher. Call an ADSCO representative or write for Bulletin 35-15H.

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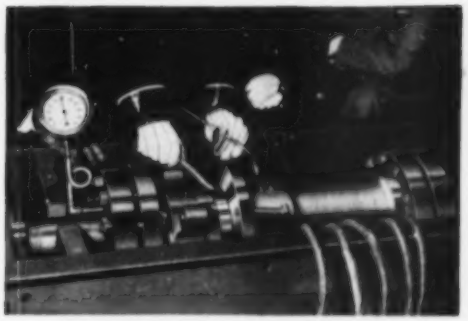
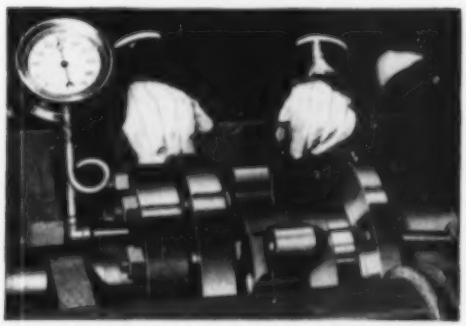


Last strand of packing being withdrawn from stuffing box.



Close-up photograph shows all packing removed. With steam at 240 lbs. pressure and with 300° superheat there is no trace of steam in the empty stuffing box.

With periodic adjustments of the gland, it may never be necessary to repack the stuffing box in an ADSCO piston-ring expansion joint. However, lack of maintenance may make it necessary at some time to do so and the job is easy with this ADSCO joint. The piston rings hold the line pressure during the unpacking and repacking operation. With the vent valve open, the vent chamber is at atmospheric pressure and, under this condition, no steam can enter the stuffing box space. Thus complete repacking can be done under full line pressure.

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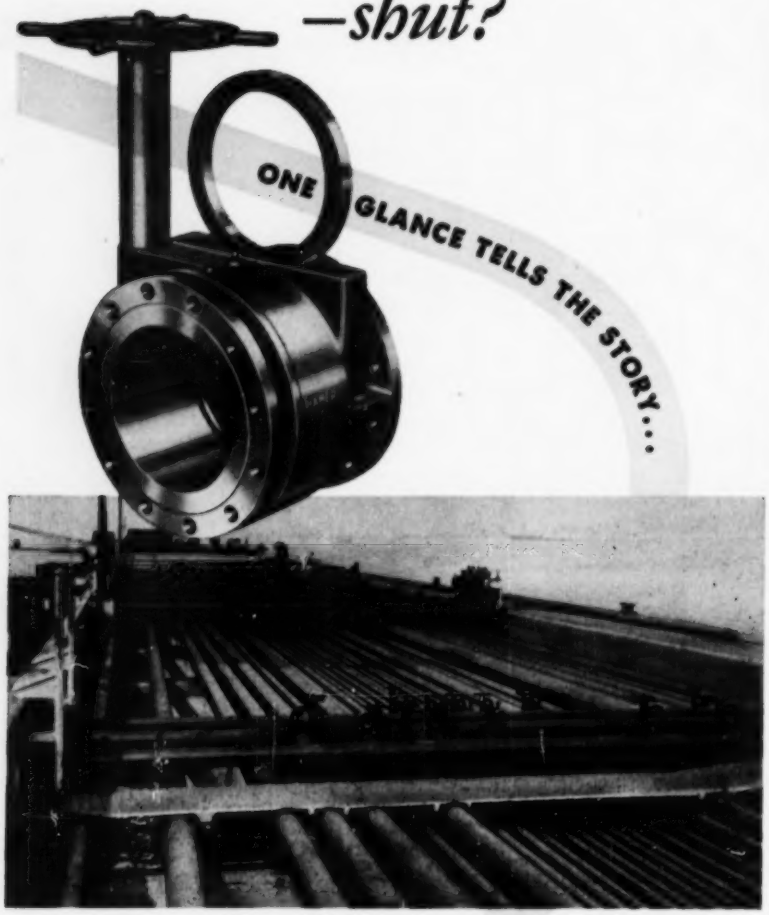
—shut?



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MARGINAL NOTES

(Continued from page 25)

formation. Since numerous references covering these aspects are given, the book might be considered a bibliography of information on related topics as well as a direct source of information on the characteristics of vegetable fats and oils.

1948-1949 Bibliographic Survey of Corrosion. Available from National Association of Corrosion Engineers, Houston 2, Tex. (1954), 346 pp. $12.50—non-members N.A.C.E.; members N.A.C.E. $10.00.

Summaries of 3,512 corrosion and corrosion prevention articles, books, and brochures published in 1948-1949 are compiled in this volume. Abstracts by 30 technical societies were canvassed regularly for material taken from more than 500 sources the world over.

The N.A.C.E. Abstract Filing Index is used to clasify the material topically. Literature is put into eight main groups in the N.A.C.E. system: general, testing, characteristic corrosion phenomena, corrosive environment, preventive measures, materials of construction, equipment, and industries. Each main group is subdivided. Topical cross-references are appended to each section.

The subject index, in addition to terms in the N.A.C.E. Abstract Filing System, lists many metals and alloys by trade name. There are more than 2,700 names in the author index; companies and associations are not listed. The appendix aids the user in locating and obtaining copies of unfamiliar foreign or domestic journals.

Books Received

Proceedings of the Seventeenth Annual Short Course for Water and Sewerage Plant Superintendents and Operators (Bulletin No. 44). Engineering Experiment Station, Louisiana State University, Baton Rouge, La. (March 10, 11, 12, 1954), $1.00.

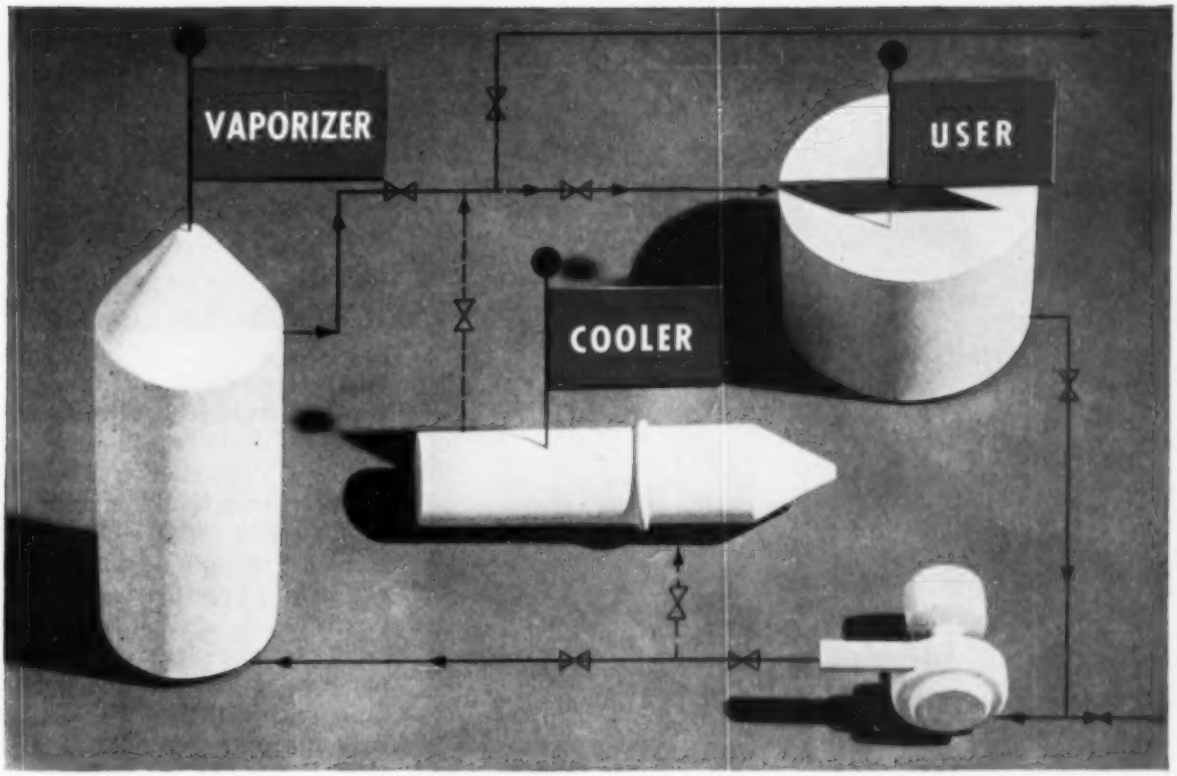
Adhesive Bonding of Metals. George Epstein. Reinhold Publishing Corp., New York (1954), 218 pp. $2.95.

Titanium and Titanium Alloys. John L. Everhart. Reinhold Publishing Corp., New York (1954), 184 pp. $3.00.

X-Ray Diffraction Procedures (for Polycrystalline and Amorphous Materials). Harold P. Klug and Leroy E. Alexander. John Wiley & Sons, Inc., New York (1954), 716 pp. $15.00.

Atomic and Free Radical Reactions (Second Edition), Vols. 1 and 2. E. W. R. Steacie. Reinhold Publishing Corp., New York (1954), 900 pp. $28.00.

DOW



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Opinion and comment

What Is a Chemical Engineer?

How often is the question asked, What is a chemical engineer? Each year it becomes more difficult to answer. The genus chemical engineer is highly mobile and involved in so many areas that no simple definition applies.

Several years ago a definition was simple. A chemical engineer was almost always closely concerned with the chemical or physical conversion of raw materials. Though he also engaged in the business side of industry, he usually found time for close supervision over field operations. Consequently, the term chemical engineer came to mean someone who dealt directly with chemical and physical energies of materials.

This is less true today, and, although many persons can still accurately be termed chemical engineers according to the old philosophy, many chemical engineers working today in the process industries function in a more complex capacity. Often they are far removed from anything but the most occasional contact with raw materials but nevertheless perform functions vital to conversion of these materials. The term chemical engineer today needs a newer and more inclusive description.

Perhaps the term is now one of qualification. It does not define a function. It is a way of thinking, a specific logic, an engineering philosophy. To accept this point of view, it is necessary to consider what each man working toward a degree in chemical engineering acquires in the way of preparation. Besides studying basic chemistry and mathematics, he is rigorously trained in the disciplines of unit operations, plant design, and other engineering subjects pertaining to the science, philosophy, and practice of chemical engineering. He is taught to think of processing as entailing a delicately balanced system complete with raw material, energy, manpower, transportation, and marketing services. And important is the fact that after he has received the basic training he is qualified to enter into the details of any step involved.

That the new graduate has entree into any of the twenty-odd process industries is indicative of the difficulty of concise definition. In addition, beginning chemical engineers undertake a wide variety of functions in these industries. Some go into process development, others into plant design. Still others prefer plant operation, and each year more and more go into marketing, which in the broader aspects includes sales. Ultimately, many find their paths leading more and more to the management of all phases of the process industries.

Why is there this great variation in function and industry for men trained similarly? We have been told by many management and personnel people that the man with chemical engineering training is usually unique in his ability to "see a process operation in its broad aspects, regardless of the individual's vantage point."

Granting that these remarks are valid, it can be reasonably asked, "But is such a man working as a sales manager, a vice-president, or an equipment vendor on a plane of chemical engineering equality with the plant manager, the process developer, or the designer?" The answer, we believe, is yes. By engaging in pursuits and exercising judgment based on the knowledge of chemical engineering, such a man is making a valuable contribution as a chemical engineer.

Owing partially to this changing aspect of chemical engineering, the Institute has under way several projects which demonstrate these facts. One will be the November issue of C.E.P. devoted to "The Chemical Engineer in Management"—a theme that will not only be of interest to persons directly engaged in managerial activities, but will also recognize the management problems faced in operation, development, design, sales, and other activities.

Another noteworthy event coming up soon is a Sunday afternoon panel discussion, to be held at the opening session of the Annual Meeting in New York in December, on "What the Young Chemical Engineer Needs from the A.I.Ch.E." The purpose is to bring out the views not only of panel speakers, but also of members of the audience.

The Institute, it seems hardly necessary to point out, is vitally concerned with improving the general concept of the chemical engineer and his activities and in securing the full recognition due him as a professional man.

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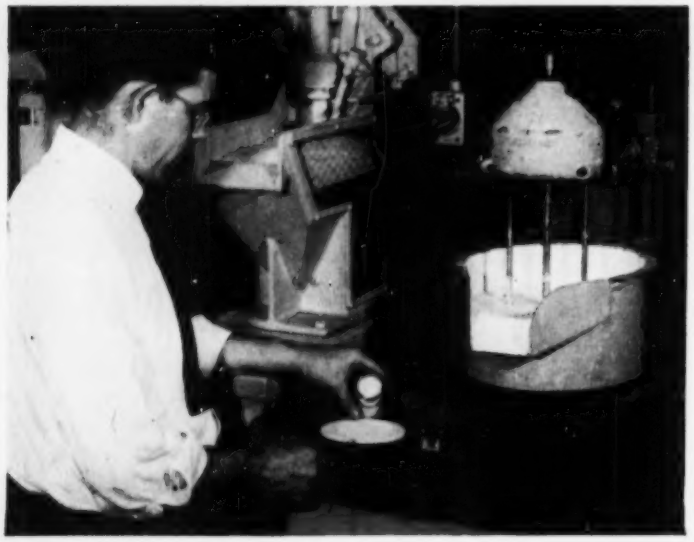

In most businesses a testing laboratory is a basic need. For designing and building mixers, the Turbo-Mixer Division has operated a fully equipped lab for many years. Here, a trained and experienced staff does all the testing necessary to obtain the data necessary for solving mixing problems.

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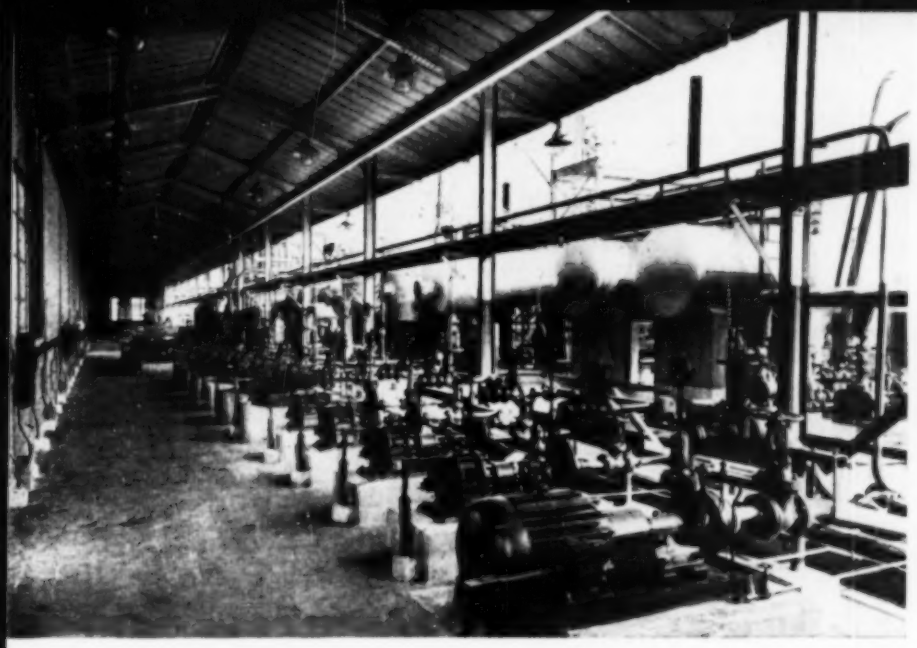


recent solutions to pumping problems

C. J. B. Mitchell | E. I. du Pont de Nemours & Company, Wilmington, Delaware

Today's chemical industry is faced with an increasing number of pumping problems. When a production plant is being designed, it is not always possible to procure a pump with the same characteristics as pumps used in the pilot plant. New processes often demand improved materials of construction. When pumping viscous materials at or near their vapor pressures, selection of each pump becomes an experimental project. Combinations of desirable or necessary characteristics when pumping slurries—such as pumping and metering without pulsation, or without crystal degradation, or agglomerate breakdown—tax the ingenuity of the pump engineer. Even selection of velocities to prevent pluggage of pump or piping when handling solids in liquid suspension often is an involved procedure.

And, accompanying each of these problems is the all-important question of the shaft seal. Should packing be used? Should a mechanical seal be used? If so, what type? Is it possible to use a pump not requiring a seal? The difficulty of providing adequate seal is always present, regardless of other problems. This article reviews several sealing devices which provide long life, uninterrupted service, and inexpensive replacement of a minimum of parts.

Sealing of the rotating shaft in pumps has been an age-old headache for process operators. Because of the increasing severity of the service conditions to which pumps are being subjected, the headache has become magnified which has brought about an all-out attack to relieve the problem. New pump designs, modifications of existing ones, and improvement in seals, are all aimed at reducing or eliminating this problem. In any study of today's pumping problems consideration must be given to the fact that

(1) Pumps, as mechanisms for transferring liquids, and frequently solids in liquid suspension, from one location to another with or without various other requirements superimposed, are high maintenance cost items, and

(2) That part of the pump where the shaft passes through the casing presents the greatest difficulty.

Two principal approaches which have been followed in the recent past toward a solution of these problems are

(a) improved sealing devices, or
(b) elimination of the need for a sealing device.

Efforts of those concerned with pumps must continue to be directed towards improving both sealing devices and pumps without seals.

The extent of the problem is reflected by fabulous pump maintenance costs; in some cases the annual figure soars to several hundred per cent of the investment. The average annual pump maintenance cost of chemical process pumps approaches 70% of the investment, and thus, the need for further development is clearly indicated. Furthermore, process advances are placing increased demands on pumping equipment.

Today's pumps must handle

(a) expensive or hazardous liquids (poisonous, toxic, or flammable)
(b) extremely viscous liquids
(c) molten metals and other liquids at temperatures up to 1,200° F.
(d) liquids acting as vehicles carrying solids, often abrasive in nature.
(e) extremely corrosive liquids, includ-

Mr. Mitchell is with Engineering Service Division.

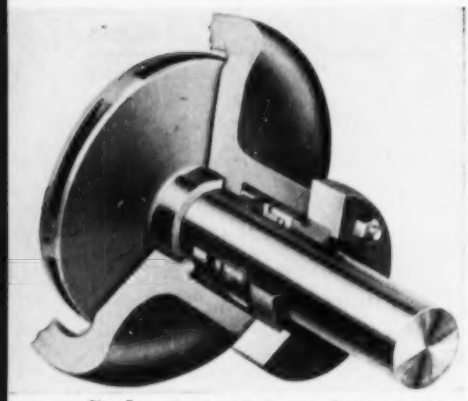


Fig. 2. *Drametallic Corp., Kalamazoo, Mich.*

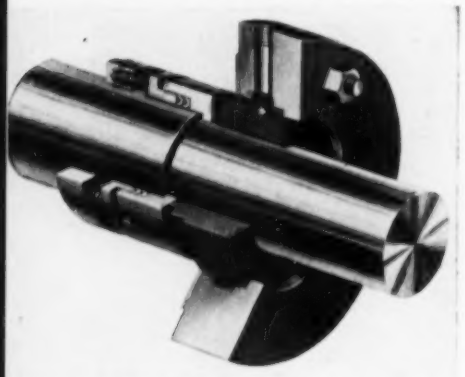


Fig. 3. *Drametallic Corp., Kalamazoo, Mich.*

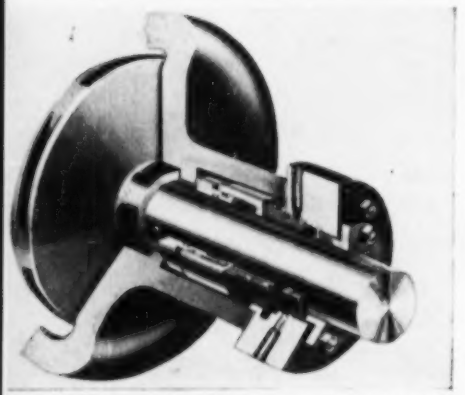


Fig. 4. *Drametallic Corp., Kalamazoo, Mich.*

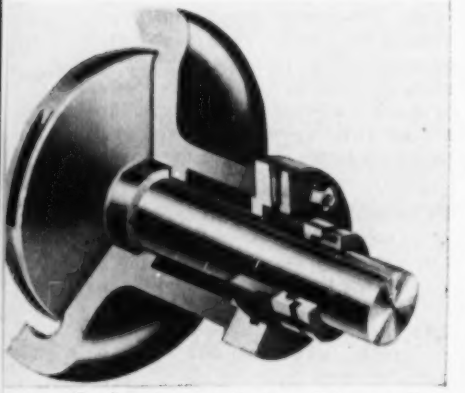


Fig. 5. *Drametallic Corp., Kalamazoo, Mich.*

ing those in nuclear processes which are emitters of neutrons, these being highly destructive to sealing materials.

The problems most usually troublesome in these applications have to do with sealing, that is, most liquids can be pumped, or moved, from one location to another with little trouble, but it is the loss of a portion of the liquid during moving that gives concern. Or, it is the escape of poisonous vapors to the surrounding atmosphere which must be guarded against in order not to endanger the lives of personnel working in the vicinity of the pumps. Then too, the fire hazard endangers wide areas when volatile liquids escape from a pump and their vapors diffuse into the atmosphere, thereby forming explosive mixtures.

Satisfactory materials of construction can be selected for handling most corrosive or high-temperature liquids and molten metals; however, it again is the escape of liquid around the shaft which poses a problem either because of freezing at the lower ambient temperature or because of incompatibility of the fluid with a humid atmosphere. Likewise, materials of construction to resist abrasion, particularly for the centrifugal pump, are available.

In brief, today's pumping problems are centered in the shaft, shaft sleeve, and packing box. The hydraulics, mechanics, and materials of construction required are, for the most part, well known.

Special Sealing Arrangements

Ideas to reduce the sealing problem are continuously being developed and improved, and these improvements pave the way for the practical use of pumps in new processes. Some of the more promising sealing arrangements are described here.

CONVENTIONAL CENTRIFUGAL PUMPS

Auxiliary or back vanes have been added to centrifugal pump impellers which prevent the escape of liquid while the pump is in operation. A stationary seal prevents leaking when the pump is shut down.

Liquid seals of the manometric type (Figure 1) and mercury seals also employing the same principle have been used.

Mechanical seals have been developed for many applications. Variations in the basic design (Figure 2) have been employed to accomplish specific objectives. Single seals of the basic design are for moderate pressures—single seals of the balanced type for higher pressures (Figure 3); cooled seals (Figure 4); lubricated seals (Figure 5); double seals with an auxiliary flushing liquid (Figure 6). These are all modifications of the basic concept.

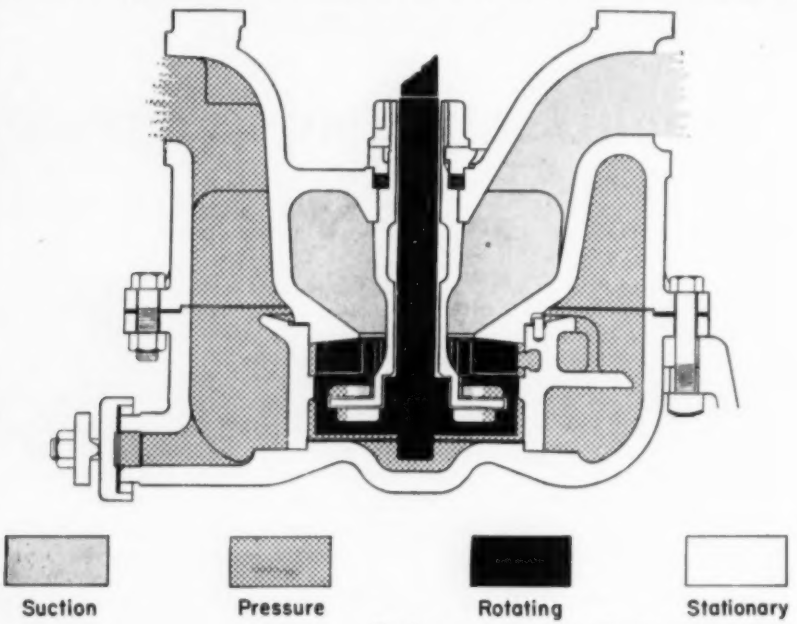


Fig. 1. *La Bour Co., Inc., Elkhart, Ind.*

PACKINGLESS PUMPS

Diaphragm Pumps

In addition to the many novel and varied sealing arrangements which have found specific applications, packingless pumps have been the subject of study for many years. The most familiar of these is the diaphragm type (Figure 7).

Diaphragm pumps may be mechanically, pneumatically, or hydraulically actuated. All three types are manufacturers' standard products.

These pumps are circumscribed as to size, pump against limited discharge pressures, and are restricted in the fluids they can handle by reason of the material of the diaphragm. One manufacturer supplies a pump with double diaphragm construction (Figure 8), the purpose of which is to prevent the escape of the pumped fluid to the atmosphere in the event of a diaphragm failure.

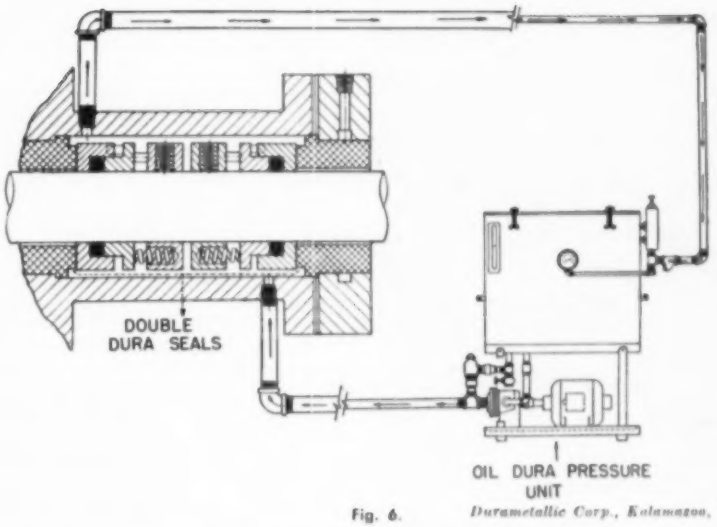


Fig. 6. *Duraметallic Corp., Kalamazoo, Mich.*

Canned-Motor Centrifugal Pumps

For general service in the chemical industry, the "canned-motor" design is perhaps the most promising for the leakproof pumps. In this design the centrifugal-pump impeller is mounted on a shaft with the conventional motor rotor. The rotor rotates in the fluid being pumped and the rotor-impeller shaft is supported on bearings which are submerged in the pumped liquid. Both the rotor and the stator are sealed from the fluid by corrosion-resistant cans or shields, thus the name canned-motor pump.

Pumps of this kind can be custom built for any hydraulic condition in the chemical industry, which is now satisfied by conventional centrifugal pumps. This type of unit finds application also in the power field for boiler water circulating pumps, for instance. At high system pressures and temperatures, the complete elimination of leakage is of major importance.

In the development of the canned-motor pump, engineers had three basic difficulties

(1) the sealing of the rotor and the stator windings from the fluid being pumped

(2) the cooling of the rotor and the stator

(3) the bearings.

The motor of the unit is of the induction type. The usual air gap is now made up of the two cans and a liquid. The stator and rotor cans must be corrosion resistant in the fluid pumped and must have high electric resistance and must be nonmagnetic. The additional electrical loss resulting from the increased length of gap has proved to be of little consequence. For many liquids suitable corrosion-resistant materials, satisfying the additional requirements, are known.

Cooling for most applications is effected by circulating a minute quantity of the pumped fluid through the bearings and motor space. This quantity generally is less than 1% of the flow.

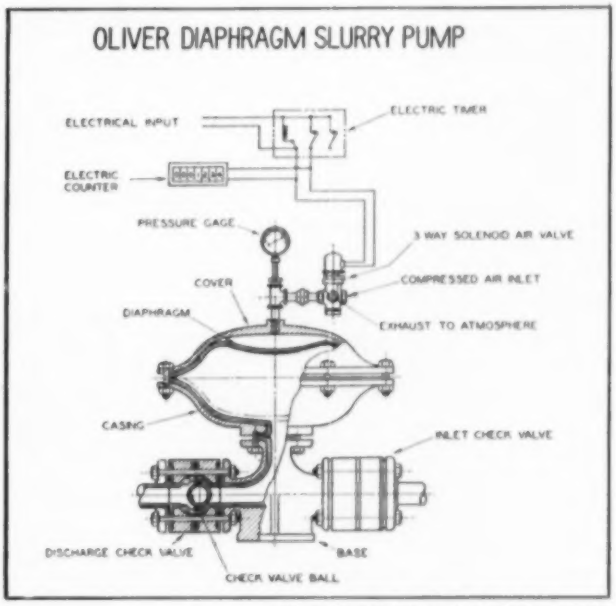


Fig. 7. *Oliver United Filters, Inc., Oakland, Calif.*

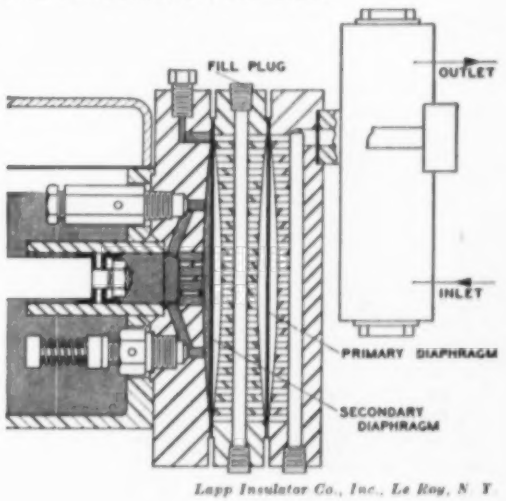
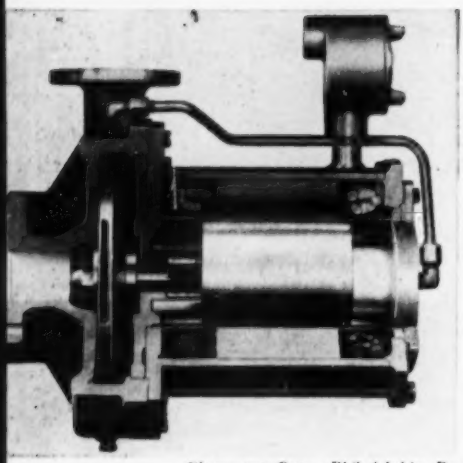


Fig. 8. *Lapp Insulator Co., Inc., Le Roy, N. Y.*



Chempump Corp., Philadelphia, Pa.
Fig. 9.

Sleeve-type bearings for radial loads and pivoted shoe-thrust bearings for thrust loads are employed by some manufacturers. The principal material of construction for the bearings is graphite, which is suitable for most nonoxidizing liquids. Other materials and metals, such as ceramics, plastics, and carbides may be suitable for particular applications.

One manufacturer can supply canned-motor pumps with sleeve-type bearings "off-the-shelf" in various materials of construction and ranging in size from fractional horsepower to 7½ hp. Doubtless larger sizes will follow as acceptance of the canned-motor principle increases. Details of this design are well illustrated in Figure 9. In the case of a hydraulically balanced impeller the thrust loads are reduced sufficiently to permit the remaining thrust to be carried on the ends of the sleeve bearings.

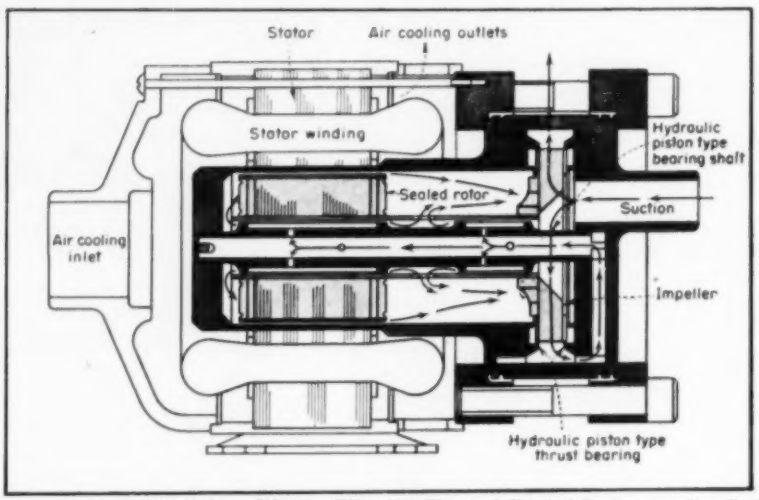
In custom-built units (Figure 10), another manufacturer can supply canned-motor pumps with fluid-piston bearings (Figure 11). The principle employed in this design permits the selection of materials of construction solely on the basis of their compatibility with the fluid. In operation the shaft or bearing journal is supported on fluid pockets. Radial loads forcing the shaft in one direction are opposed by unequal pressures in the fluid pockets, thus providing a restoring force. Metallic contact occurs only during stopping and starting. In a recent release an important government agency reports that during an accelerated life cycle of more than 1,000 starts and stops, no measurable loss of performance was noted.

Special designs of canned-motor pumps can be made for more difficult services. For handling liquids at elevated temperatures, Class H insulation can be used. Air or liquid circulation through the stator windings can be used for cooling. A heat exchanger can be used in the recirculation line so that only cool liquid is circulated through the motor space. For handling slurries or viscous liquids, a clear mother liquor or less viscous liquid can be circulated through the motor space.

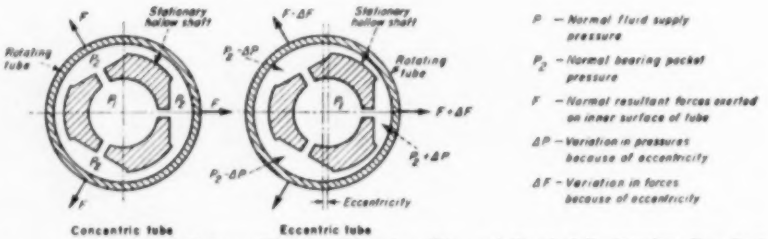
Electromagnetic Pumps

Principally an outgrowth of the atomic energy program, these pumps were developed for the pumping of liquid metals. No longer laboratory infants, several types of these pumps are now set to take their place as usable process equipment.

The principle of the Faraday d.c.-type electromagnetic pump is illustrated in Figure 12. A constant magnetic field is



Allis-Chalmers Mfg. Co., Milwaukee, Wis., and Chemical Engineering, *New York*
Fig. 10.


Stationary hollow shaft
Rotating tube
Concentric tube
Eccentric tube
Eccentricity
P = Normal fluid supply pressure
P2 = Normal bearing pocket pressure
F = Normal resultant forces exerted on inner surface of tube
ΔP = Variation in pressures because of eccentricity
ΔF = Variation in forces because of eccentricity

Allis-Chalmers Mfg. Co., Milwaukee, Wis., and Chemical Engineering, *New York*
Fig. 11.

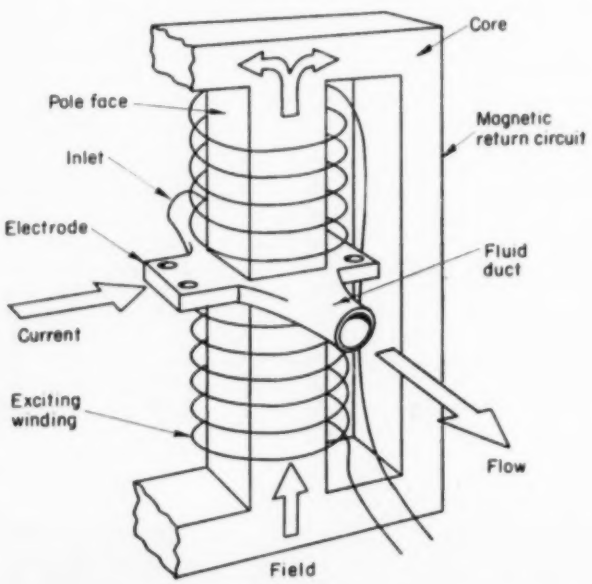


Fig. 12.

passed through the fluid on one axis perpendicular to the direction of flow. Current is forced through the fluid by impressing a voltage across the axis of the duct mutually perpendicular both to the field and to the direction of flow.

Electric motors make use of this same principle. In the case of the pump, output is the movement of a confined fluid conductor, and the output of a motor is the movement of a solid conductor on a rotating shaft.

A description of several types of electromagnetic pumps is contained in a report by J. F. Cage, Jr., of the Knolls Atomic Power Laboratory.

Faraday d.c. Pump (Figure 13)

The Faraday d.c. is the most rugged and dependable of the electromagnetic types. Units in which the windings are cooled by natural convection have operated with fluid temperatures as high as 800° F. These pumps operate on low voltage—in the neighborhood of 1 v., and at extremely high currents. For this reason they have not been used where large fluid horsepowers are required. However, they have been built for capacities as high as 400 gal./min. and for heads as high as 100 ft.

Faraday a.c. Pump (Figure 14)

The Faraday a.c. is another version. A transformer can be used with this pump and is usually built as an integral part of the unit. Because of the low efficiency (up to 15%) and bulky electrical requirements, applications of this type pump have been limited to laboratory-sized units.

Helical Flow Induction Pumps (Figure 15)

The helical flow induction pumps have been built for relatively high pressures and low flows. Heads as high as 260 ft. of sodium have been developed. One design delivers 400 gal./min. of sodium against a developed head of 60 ft. This unit weighs 1,500 lb., operates on 25 cycles/sec. at a power factor of 80% and requires 1,000 cu.ft./min. of air for cooling the windings.

Linear Induction Pump (Figure 16)

The linear induction pump is best suited where relatively large flows at moderate heads are required and where space and power are at a premium. Forced convection cooling systems are required. One unit of this type delivers 1,200 gal./min. of 850° F. sodium for 110 ft. developed head at 300 v., 288 amp., 0.45 power factor, 60 cycles/sec. The unit weighs 6,430 lb. and requires 2,000 cu.ft./min. of cooling air.

Compared with standard centrifugal pumps, the electromagnetic types suffer in efficiency, size, and weight. Their application is warranted where completely leakless operation is imperative.

Task Ahead

Further pump developments must go hand-in-glove with operating experience. In terms of gallons per minute, and head in feet, or pressure in pounds per square inch, many of the newer designs are extremely expensive at present. However, in terms of reduced maintenance cost, reduction in downtime, elimination of product loss, and increased safety, the packingless pumps hold a tremendous potential.

Most of the pumping problems will remain unsolved during the foreseeable future. The reasons for this are twofold: First conventional pumps cannot be replaced on a wholesale basis, and second each increment of improvement will have to be achieved on the proving ground of actual operating plant experience.

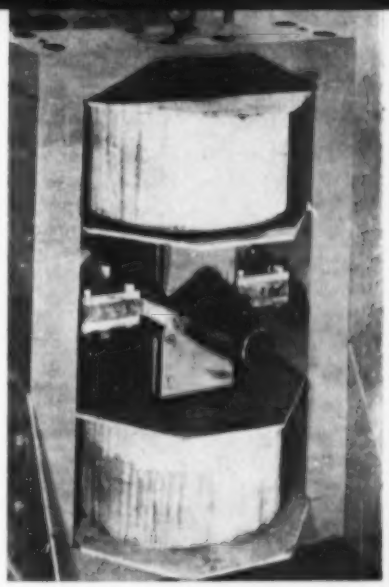
Acknowledgment

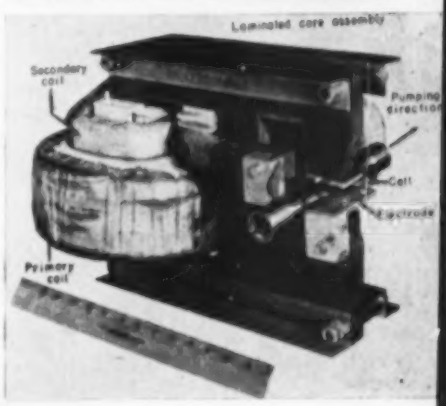
The author wishes to thank the following organizations for their cooperation in supplying illustrations for this article: LaBour Co., Inc., Elkhart, Ind.; Durametallic Corp., Kalamazoo, Mich.; Oliver United Filters, Inc., Oakland, Calif.; Lapp Insulator Co., Inc., LeRoy, N. Y.; Chempump Corp., Philadelphia, Pa.; Allis-Chalmers Manufacturing Co., Milwaukee, Wis.; and *Chemical Engineering*, New York, N. Y.; *Product Engineering*, New York, N. Y.; *Machine Design*, Cleveland, Ohio; Knolls Atomic Power Laboratory, Schenectady, N. Y., operated for the U. S. Atomic Energy Commission by the General Electric Co.

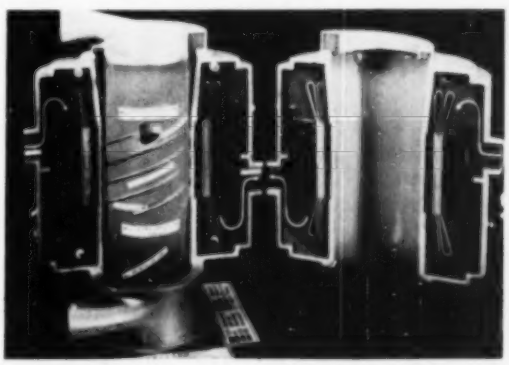
Also the author cites A.S.M.E. for use of information, which appeared in *Mechanical Engineering*, June, 1953, on electromagnetic pumps.

Presented at New Jersey Local Section meeting.

Picture of pump installation on page 431 supplied by The Lummus Co.







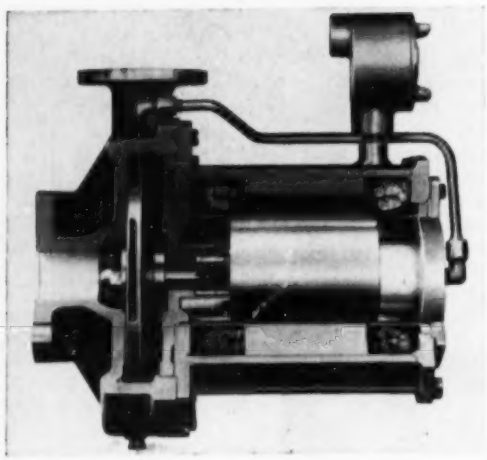
Top—Fig. 13.
Second from top—Fig. 14.
Left—Fig. 15.
Below—Fig. 16.

Figs. 13-16. Knolls Atomic Laboratory, Schenectady, N. Y., operated for the U.S. Atomic Energy Commission by the General Electric Co.

design and development of seal-less pumps

D. P. Litzenberg and H. T. White

Chempump Corporation, Phila., Pa.



David P. Litzenberg and Howard T. White are directors and vice-presidents of Chempump Corporation. Both are graduate engineers and have had extensive experience in mechanical and electrical development and design programs.

The elimination of mechanical seals and stuffing boxes in centrifugal pumps is the ideal solution to the industry-wide problem of high maintenance and leakage costs. Vast sums of money are lost annually through stuffing-box leakage and through the excessive maintenance that packing and seals require. One company, for instance, spends $26.00 per pump each week on packing and labor costs alone, and this figure does not include fluid losses.

In addition to reducing costs, seal-less pumps offer ideal or considerably improved solutions to difficult applications such as:

1. Unusual Pressure Conditions

Operations, requiring pumps to function at high suction pressure and discharge against a comparatively small differential head, impose severe stresses on stuffing boxes.

2. High Vacuum Service

Maintaining a high vacuum poses a problem whenever stuffing boxes are involved as any slight eccentricity or wear in the shaft permits air to enter through the packing.

3. Cycling Vacuum and Pressure Service

Conventional packing or sealing methods for vacuum applications cannot normally be used for pressure applications also.

4. Pumping Valuable Liquids

Quantities of valuable liquids are lost each year through stuffing-box leakage. In addition to the expense involved, such losses make it difficult to obtain accurate material balances.

5. Toxic Liquid Service

Safety engineers are extremely conscious of stuffing boxes as sources of dangerous fumes.

6. Explosive Vapor Conditions

Eliminating the leakage—a source of explosive vapors—is a safety provision which removes a potential hazard. An additional factor is that a stuffing-boxless pump has no packing to blow out in case of explosion.

7. Radioactive Liquid Service

The release of radioactive liquids from leaking stuffing boxes cannot be tolerated. Furthermore, most packing materials do not withstand long periods of contact with radioactive fluids.

8. Corrosive Liquid Service

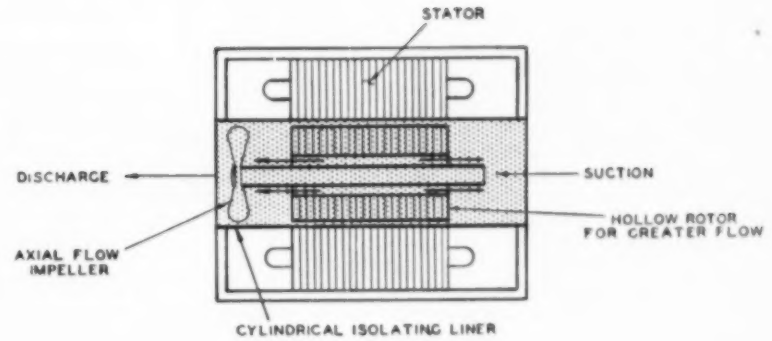
In addition to localized corrosion, which can occur from stuffing-box leakage, vapors from corrosive leaks can damage other process equipment.

9. Noxious Liquid Service

Working conditions can become unbearable when foul odors are created by leaks from stuffing boxes.

10. Sensitive Liquid Service

In seal-less pumps there is no danger of contamination of liquids by air, moisture, packing lubricant, or other foreign matter which would cause gumming, crystallization, or other trouble.



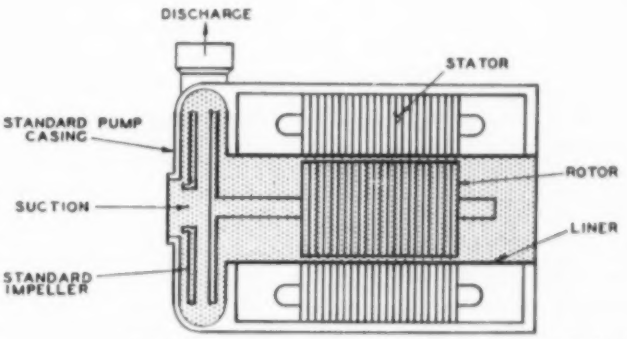


Fig. 1. Basic design. Pumped fluid fills rotor cavity; cylindrical liner in stator isolates windings. Principle patented in 1940.

Early Design Program

The basic problem in the design of a seal-less leakproof pump revolves around power transmission. A method is needed to drive the impeller of the pump without the use of a shaft which extends through the pump casing to the prime mover. Three methods were selected as the most feasible and worthy of further investigation.

A. To introduce metallic particles into the pumped fluid which would be set into directional motion by a magnetic field and which, in turn, would impart motion to the fluid.

B. To attach permanent magnets to the pump impeller which would be driven by motorized magnets on the outside of the pump.

C. To build the pump inside the motor or the motor inside the pump; in other words, to produce a combined motor-pump.

As early as 1900, ideas along the lines just referred to were considered, and sporadic attempts were made to turn them to good account. However, it was not until the late thirties and early forties that a concrete program was established to investigate the above-listed proposals. The program was interrupted by World War II but was completed shortly after its conclusion with the production of the first successful seal-less centrifugal pump unit.

Determining the One Best Method

In the early stages development work on all three proposed methods, namely A, B, and C was carried on in parallel programs, until thorough testing and analysis indicated the one proper course to follow.

Method A was the first to be discarded because of severe limitations imposed by the introduction of metallic particles in the fluid being pumped. Although tests were successful, there were numerous hydraulic and mechanical limitations.

Method B, involving internally and externally driven and driving magnets, was found to have severe torque and efficiency limitations in a design that required three magnetic air gaps: one in the motor, one between the impeller magnets and a separating disc, and one between the disc and the driving magnets. The detrimental effect of these gaps increased when the impeller magnets were incased in corrosion-resistant materials.

The success of initial efforts on Method C resulted in a decision to base all further work on the combined pump and motor approach. This design satisfied all the basic requirements, and indicated from the start that it would eliminate the limitations inherent in the other methods. Work progressed rapidly, and in 1947, the first production unit, a fractional horsepower model, was sold to industry. The pump has been placed in 20,000 installations throughout the country.

The Basic Seal-Less Design

In order to build the pump within the motor, or vice-versa, it was necessary to develop a method of isolating the electric motor stator from the fluids being pumped. Tests showed the use of a nonmagnetic cylindrical sleeve installed in the air gap of the motor to be the most practical and successful method (see Figure 1). The rotor of the motor, spinning in pumped fluid which was allowed to enter and fill the cavity created by the sleeve, was driven magnetically by the stator field in the same manner as an ordinary induction motor. The pump impeller was directly attached to the rotor. In some series of tests, the impeller was placed inside the stator sleeve and in other cases it was extended beyond it to an external pump casing. The latter procedure was necessary to obtain impeller diameters sufficient to do the work required.

Since the motor rotor was to rotate in the pumped fluid, and, in cases of

corrosive fluids, needed protection from the material, this part was also covered or "canned" with a noncorrosive and nonmagnetic material. This gave rise to the expression of a "canned rotor pump" when describing the basic design. Actually this description would be more accurate if the expression "canned motor pump" were used since in many cases it is unnecessary to protect the rotor.

Figure 2 shows the seal-less pump design which appeared in 1947. As seen in the simplified illustration, pumped fluid was delivered through the center of the rotor. Impeller diameter was limited by the inside diameter of the stator consequently limiting the pressure and flow delivered. Extensive testing and experimentation determined that less than 1 hp. was obtainable by this design. It was also found that the unit could not handle slurries.

Further investigations were undertaken to overcome these objections as well as to enable accommodation of high temperatures and high pressures.

To meet these requirements, the designers developed the unit illustrated in simplified form in Figure 3, in which the impeller was placed outside the rotor chamber. Except for a small amount in the rotor chamber, all pumped fluid was confined to the pump chamber. Cooling cores around the outside of the stator and a hydraulic balance chamber provided for high temperatures and high pressures.

Development and field tests of these early units produced many facts. One of the most important was that a single pump, capable of handling all the possible problems of temperature, pressure, etc. was not economically sound. Two designs were needed: one to handle the majority of applications, and a second to handle those involving extremes of temperature and pressure. Surveys indicated that a majority of indicated seal-less pump applications could be handled by a nonmodified standard model.

This standard model, or refinements of it, is the basis of the present Chempump Models C and CF. The model C will be used as an example in the following description of design and development.

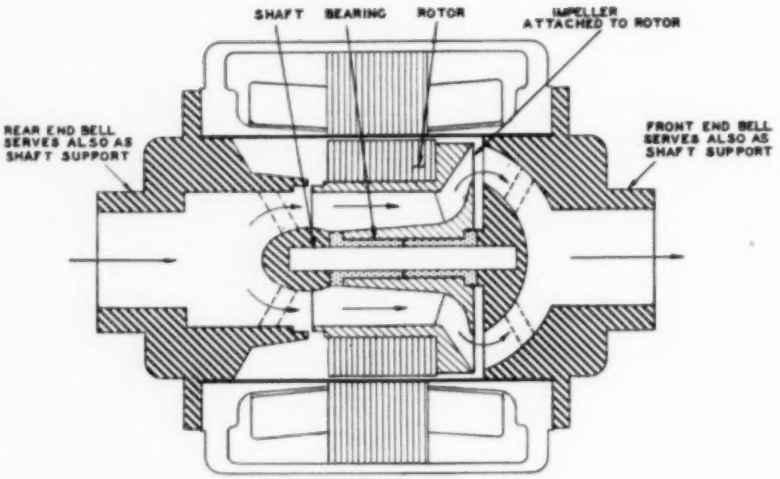


Fig. 2. First production model (1947). Pumped fluid flows through center of rotor, impelled by vanes attached to rotor assembly. Thrust and radial loads taken by single bearing.

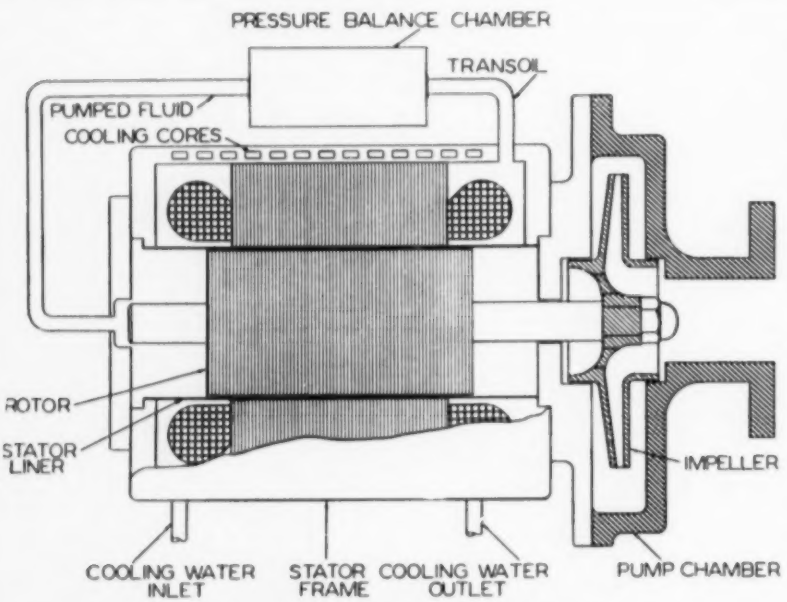


Fig. 3. 1948 model of pump for high temperatures and high pressures. Note impeller extended beyond stator to provide increased impeller diameters.

General Design Considerations

A number of basic design considerations should be discussed before reference is made to specific details. Electric motors are built to close tolerances. Centrifugal pumps, on the other hand, are generally built to rather wide tolerances. Consequently, when building a combined motor-pump, it is necessary to design all parts to fit in with, and work with, the closest tolerance needed in the complete structure. This of course establishes much higher standards for the actual pump parts than has heretofore been necessary or used in the industry.

Another basic problem is the fact that all electric motor stators require cooling. In most cases a fan attached to the motor rotor provides this necessary cooling. Since in a seal-less design the rotor is submerged in the pumped fluid and is placed in a separate chamber from the stator, this method of cooling is unavailable to designers.

A last general problem relates to the use of submerged bearings, which, of course, are necessary. After a thorough search Chempump engineers found that little work had been done on this point, particularly in the investigation of the various speeds that would be required, the bearing loadings including thrust conditions, and the materials that could withstand corrosive effects of the actual pumped fluids.

Detailed Design Considerations

Since the pump section, consisting of a volute and impeller, is standard, no

OPERATING CASE HISTORIES

The following operational reports give some performance history in actual industrial applications. The standard Chempump model is referred to in these case histories.

User: Electron tube manufacturer.

Fluid Handled: Potassium silicate.

Service Report: In April, 1953, a ½-hp. Chempump was initially placed on 24-hr. service and operated for five months with no maintenance or downtime. It was then placed on 16-hr.-a-day service, and has since operated with no maintenance or downtime. Total bearing life is now more than 10,000 hr. without any indication of needed replacement. Previously the potassium silicate, which hardens immediately on contact with the atmosphere, has caused excessive scored shaft replacement, as well as frequent repacking of the stuffing box. Chempump has saved this company more than $1,500 to date, a sum which represents more than five times the initial cost of the pump.

User: Large Midwestern petrochemical operator.

Fluid Handled: Perchlorethylene.

Service Report: A 2-hp. Chempump was initially installed to evacuate distillate under flooded suction from a vacuum still at 24 in. Hg vacuum. The pump produced 45 gal./min. against a 50-ft. head with no air leakage or contamination. The unit was placed on perchlorethylene service and ran about eight months before the bearings were changed. Other Chempumps which were purchased have been used with carbon tetrachloride, and unrevealed fluids.

User: Plastics manufacturer.

Fluid Handled: Toluene.

Service Report: A 3-hp. cast-iron Chempump has been pumping this fluid for more than nine months with no indication of needed bearing replacement. Leakage and maintenance, it was stated, formerly cost the company $700 a year, not including downtime. This company is also using Chempumps to handle Dowtherm and vinyl chloride. Facts on operation are not reported.

User: Large integrated oil refinery.

Fluid Handled: Aldehydes.

Service Report: This company has used Chempump on this and other services for more than nine months. Both O ring pumps and welded construction units are reported as having given satisfactory service.

User: Producer of oil additives.

Fluids Handled: Alcohols (propyl and methyl amyl) and turpentine.

Service Report: Original Chempump unit was changed from alcohols to turpentine service and user bought a second larger pump to handle the alcohols. Original unit has operated for more than a year, without maintenance, while the second unit has been in maintenance-free operation for eight months.

User: Aircraft plant.

Fluid Handled: Cadmium plating solution, other corrosive fluids.

Service Report: A 316 stainless steel Chempump was installed to circulate several solutions through a filter—previous stuffing box pump having caused a wide variety of corrosion and contaminating problems. Chempump operation has been intermittent, which makes such an application even more difficult, but operation has been reported satisfactory at end of ten months.

User: Synthetic textile yarns manufacturer.

Fluid Handled: Pulp digester liquor at 400° F.

Service Rejort: A ¾-hp. stainless steel model has been used on this application for more than seven months. No bearing problems have been experienced. User has recommended Chempump to other pulp and cellulose processors.

User: Electrical switch gear manufacturer.

Fluid Handled: Trichlorethylene.

Service Report: A ½-hp. cast-iron unit has pumped this fluid on a degreaser for more than nine months. Previous pump had to be repacked two and three times a week, and company was losing approximately 25 gal. of trichlorethylene every 24 hr. through the stuffing box. Total running time to date for Chempump is 3,000 hr. without leaks, maintenance, or bearing replacement.

discussion of it nor of the theory of operation of induction motors will be taken up. Only those design problems relating specifically to the seal-less motor-pump and the methods of their solution will be commented on here.

MOTOR-STATOR

The two major considerations in the design of the stator are isolation of the windings and other stator parts from the pumped fluid, and the obtaining of the necessary cooling for the assembly.

With reference to Figure 4, it can be seen that isolation of stator parts from the fluid being pumped is accomplished by the insertion of a cylindrical sleeve or liner in the inside diameter of the stator. First this liner should be relatively thin since it must occupy a portion of the air gap of the motor. Second it must have high electric resistance and nonmagnetic characteristics to prevent excess electrical losses. Third it must be more corrosion resistant than any other section of the pump unit because of the thinness of the metal.

LINER THICKNESS VS. ELECTRICAL LOSSES

In determining optimum balance between allowable thickness of the stator liner and allowable electrical losses, it is necessary to explain that the air gap of an electric motor increases slightly with the horsepower of the motor. A ⅛-hp. motor usually has an air-gap dimension of .010 in. maximum, and a 3-hp. motor .015 in. maximum on a side. In a combined motor pump, even if the air gap were to be increased, the isolating liner must be of very thin material, since a portion of the gap area must be retained to provide running clearance for the motor rotor.

Tests indicated that with a modification in motor design, this air gap could be increased to accommodate a liner approximately .020 in. in thickness, provide a .010-in. cover for the motor rotor, and still retain ample running clearance. These close tolerances called for high-precision manufacture.

Tests of a 3-hp. pump showed that the use of this liner presented a loss of only 50 w. over and above the wattage necessary to operate a standard 3-hp. motor. This is less power than that required to overcome the friction imposed by a seal or stuffing box.

LINER THICKNESS VS. CORROSION RESISTANCE

It was obvious that no one material could be used for the stator liner be-

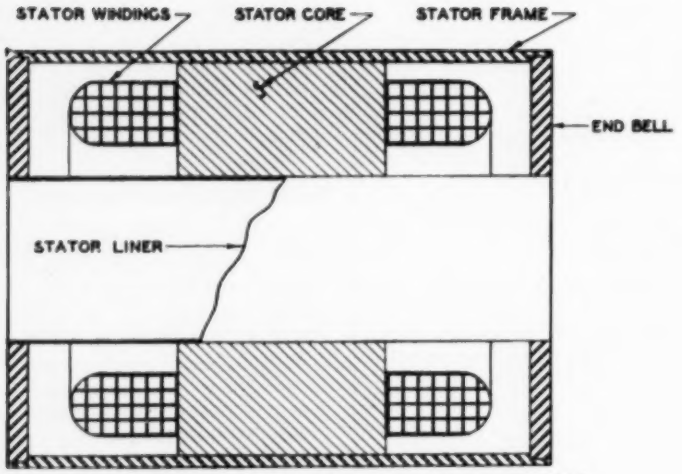


Fig. 4. Basic stator assembly design. Present Chempump Model C series has liner welded to end bells.

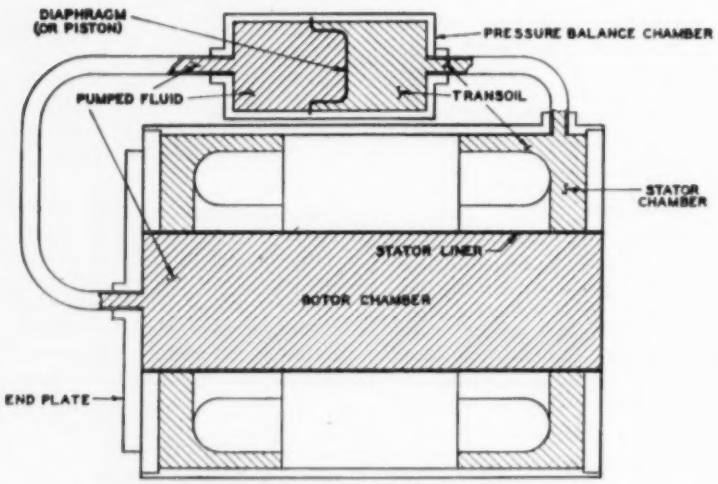


Fig. 5. Early method to handle high pressures by pressure balanced on both sides of stator liner.

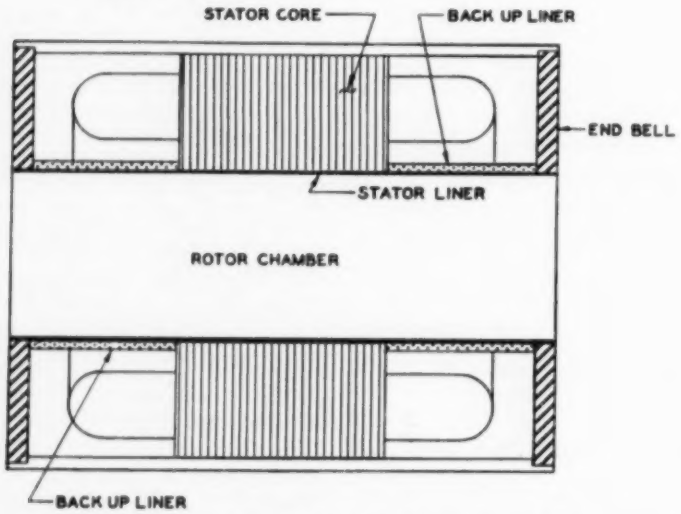


Fig. 6. Improved method for handling high pressures uses cylindrical back-up liners along unsupported sections of stator liner.

cause of the varying natures of the different fluids to be pumped. Testing was carried out on such metals as titanium, Hastelloy, zirconium, stainless steel, Invar, Inconel, and Monel to determine their effects on the electrical characteristics of the motor. These materials and others, including certain plastics, have been successfully used.

Because of the relative thinness of this component, it was not possible to be guided by normal corrosion rate factors which the chemical process industries rely on in general design matters. As a result, liners of rare metals are frequently used in the production of ordinary stainless steel or cast-iron pumps in order to obtain a very low corrosion rate. Annealing, passivating, and other forms of increasing the corrosion resistance are commonly employed.

LINER THICKNESS VS. LINE PRESSURES

The thinness of the stator liner also raised the problem of deformation due to high line or internal pressures inside the pump. A test program was established which demonstrated that a .018-in. liner would withstand pressures to 300 lb./sq.in. without deformation. In one test a liner withstood pressures of 1,500 lb./sq.in. without bursting but deformed where not backed by the stator core or end bells.

As stated earlier a hydraulic pressure balance arrangement, consisting of a tube connected from the rotor chamber of the motor to an external pressure chamber was developed shortly after production began on the first seal-less pump model. A more detailed illustration of the system is shown in Figure 5.

Rotor chamber pressure was thus applied against a piston in one design and against a diaphragm in another later design. Another tube was connected from the opposite side of the diaphragm or piston to the pump stator chamber which was filled with Transoil or similar material. This arrangement equalized the pressure on both sides of the liner.

Unfortunately, many disadvantages were found with this system, such as diaphragm or piston failures, deterioration of the motor windings, leakage through fittings, difficult reassembly in the field, and others.

In 1952 this hydraulic balance method was superseded by an improved method. Since the stator liner was supported by the stator core and the end bells over most of its surface, it was necessary to provide support only in the unsupported sections. Accordingly, all high pressure units, 150 lb./sq.in. and over, were equipped with back-up liners of the necessary thickness and strength be-

tween the end bells and stator. This back-up arrangement is shown in Figure 6.

END-BELL CONSIDERATIONS

It was necessary to provide for a gas- and liquid-tight joint at the end bells. Early models used O rings at this point, and, where it was possible to use resilient materials, these rings were satisfactory. Special O rings for highly corrosive service and for certain fluids presented problems, however, and it was necessary to develop a technique of welding the thin stator liner to the relatively thick end bell, thereby eliminating the O ring contruction. A suitable welding technique was developed, and at the request of the A.E.C. and certain industrial users, this method was adopted on all models.

STATOR COOLING

In the early stages of the development program, the designers used a system of water-jacketing the stator assembly with either external coils or cores cast in the stator frame.

These systems were only partially successful in that no cooling was achieved for the motor rotor. Often, thermocouple tests indicated that the portion of the winding wire close to the inside diameter of the stator developed excessive hot spots which caused deterioration of the winding insulation.

Another system designed in the early stages of the program used Transoil or a similar fluid sealed into the stator windings and circulated through a heat exchanger. However, insulation deterioration was also experienced with this method. Furthermore, very little cooling was afforded to the motor rotor and none to the bearings.

IMPROVED COOLING METHOD

To overcome these deficiencies, a method was developed that achieves positive and dependable cooling. This method is as follows:

A tube is connected from the high pressure side of the pump volute to the rear of the rotor chamber (see Figure 7). Due to the pressure differential between the high and low side of the pump, a small amount of the pumped fluid is circulated through the rotor chamber, cooling the inside diameter of the stator, the rotor, and also the pump bearings. The amount of fluid used for this purpose is regulated, and averages about ¼ to ½ of 1% of the total fluid handled by the pump. This volume is less than that normally recirculated by the wearing rings of a standard pump and therefore does not result in any appreciable loss of efficiency. In the case of slurries mother liquor is fed into the

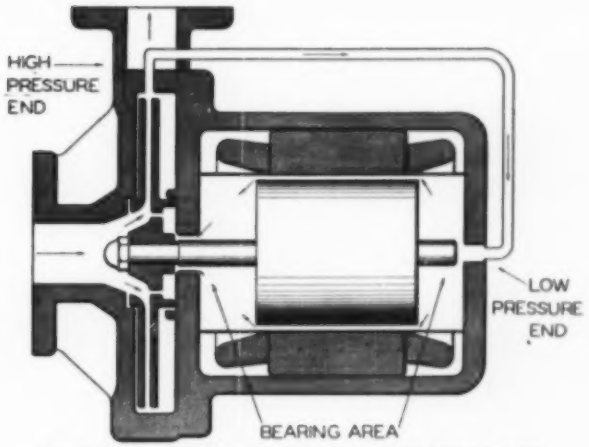


Fig. 7. Improved method of cooling uses a fluid circulation line between high- and low-pressure sides of pump. This is method used in present Model C series.

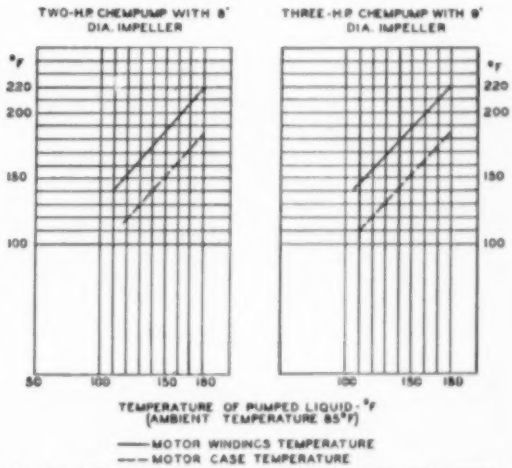


Fig. 7a. Relationship between motor temperatures and pumped fluid temperatures. 220° F. is maximum temperature limit for Class A insulation. Wire-to-water efficiencies did not change over temperature range shown.

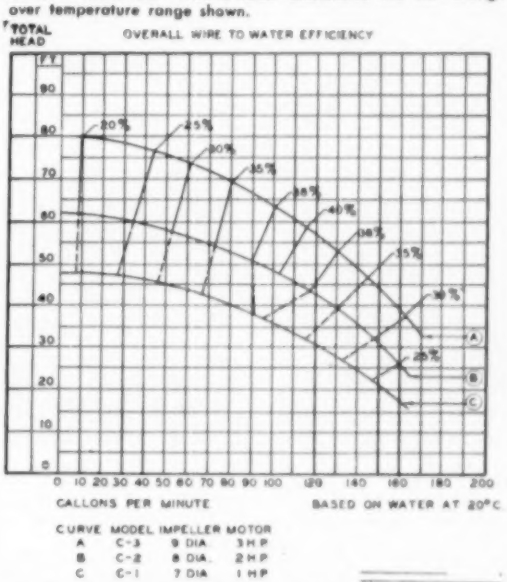


Fig. 7b. Wire-to-water efficiency of combined motor-pump. Efficiencies do not change when temperature of pumped fluid varies. Speed of rotation, 1750 rev./min.

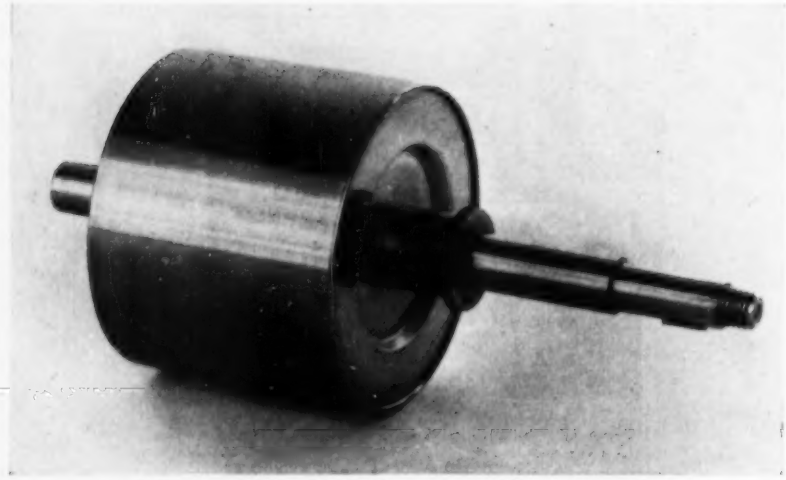
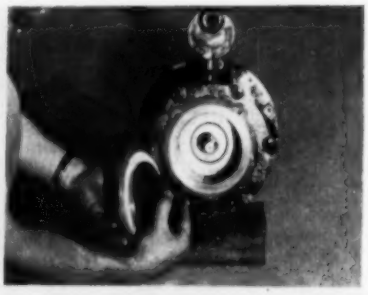


Fig. 8. Assembly consisting of rotor (encased in stainless steel) and shaft. One thrust washer is visible.



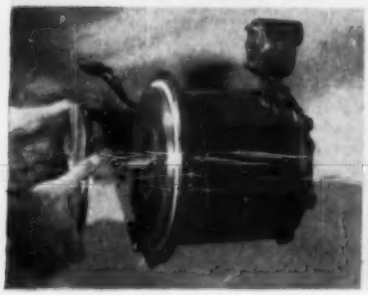


Fig. 9.

a. Chempump Model C mounted in pipeline.
b. Ring bolts removed, the pump is drawn off the volute. No piping connections are broken.
c. Removing the impeller will allow rotor to be withdrawn when back plate is removed. No puller is necessary.

Fig. 10.

a. Back plate removed and being held while rear bearing is withdrawn by hand from housing. *Note* position of rotor and stator lining.
b. Rotor being withdrawn from stator to expose front bearing.
c. Front bearing removed from housing. *Note* stainless steel case around graphitar bearing material.

rear of the unit, which provides cooling and also keeps abrasives out of the rotor chamber and away from the bearings.

No discussion of cooling is complete without reference to the temperature problem that results when hot fluids are pumped. A normal Class A insulated motor winding is rated for 105° C. or 221° F. The standard Chempump is limited to fluids of 180° F., which gives a considerable safety margin. For temperatures up to 450° F., Class H winding is used.

There are many cases that require the handling of fluids around 600° F., such as Dowtherm and oil heat-transfer agents. By inserting a heat exchanger in the fluid circulating line these hot fluids can be taken care of satisfactorily.

Tests have indicated that on 600° F. pumping applications, the winding temperature does not exceed 350° F. with a heat exchanger. This is well within the limits of Class H insulation. In addition, bearing life is greatly increased in this type of installation. A Chempump design available to handle much higher temperatures is shown in simplified form in Figure 13.

Rotor Design Considerations

Though not particularly complex, the rotor assembly has certain important design features.

In order to create the larger air gap required by the stator liner, it is necessary to remove metal from the outside diameter of the standard induction motor rotor used in the pump. Great care must be exercised in machining the rotor so as not to affect its electrical characteristics, and thereby, the motor efficiency.

The prepared rotor is shrunk on the shaft and is "canned" with stainless steel or some other corrosion-resistant material comparable to that used in the stator liner. Since rotor replacement due to corrosion is not so critical as stator replacement, and since it is desired to keep the air gap of the motor as small as possible, this rotor cover rarely exceeds .012 in. in thickness. Welding end plates to the "can" and to the shaft completes the assembly except for the installation of the thrust washers on either side of the rotor. This final assembly is shown in Figure 8.

BEARINGS

To provide a long and trouble-free operating life, the bearings in a combined motor pump must be aligned as perfectly as modern machine practices will allow. All parts of the combined structure must be held to much higher tolerances than those found

in either a standard motor or a standard centrifugal pump, and a program of rigid quality control has had to be initiated and kept constantly in force. In particular, precise control is maintained over the rotor assembly, the bearings themselves, the bearing housings, and the stator frame structure.

Since there was little information on submerged operation, another basic problem confronting the designers was the bearing material itself. This situation called for a program looking toward the development of adequate design data.

Loading problems, surface speeds, proper clearances between shaft and bearings for both lubricating and nonlubricating fluids, mating materials, mechanical surface finishes and surface treatments, such as plating, nitriding, etc., were investigated. The program embraced the use of plastics, metals of all types, including the carbide groups, graphite and ceramics.

Graphite was found to offer a partial solution to the problem if used in fluids that did not affect the material. The first production pumps were equipped with this material operating against a honed stainless-steel shaft with correct clearances to obtain the maximum film strength from the fluid being pumped. Results obtained from thousands of installations handling fluids such as water, carbon tetrachloride, trichlorethylene, titanium tetrachloride, butane, alcohol, turpentine, ether, and many others proved the acceptability of this bearing in nonoxidizing fluids in the proper temperature range.

In view of the early success of this material, the wear factors obtained in these tests were established as standards to measure the success of other materials. Bearings have been developed and are available to handle nearly every type of service.

NEW BEARING DESIGN

All bearings eventually wear out; therefore Chempump engineers have provided a new design which allows the changing of the worn-out bearings within a few minutes without the use of special tools. (Figures 9 and 10.)

Bearing alignment is obtained and maintained by shrinking the bearing material into a bearing holder. The assembly is honed on the inside diameter and ground on the outside diameter to a close tolerance so that complete concentricity and alignment result.

Because of the simplicity of a sealless pump, it is possible to operate it at high speeds. Such operation offers advantages of higher efficiency and in-

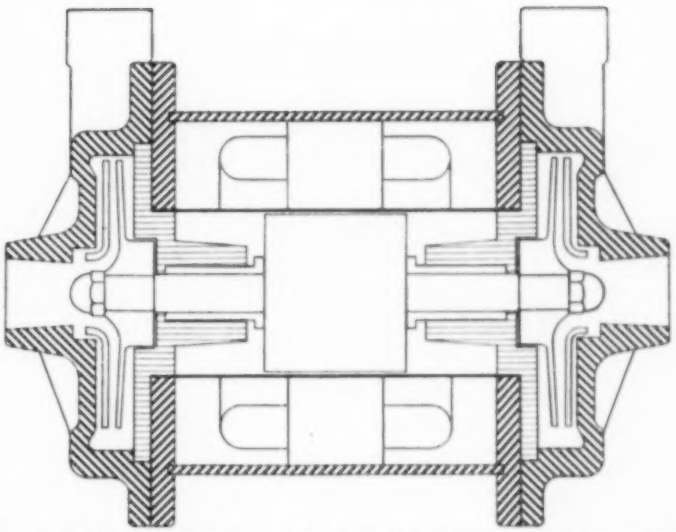


Fig. 11. Double-ended Chempump. High volume, high head pumping employs parallel or series manifolding of intake and discharge.

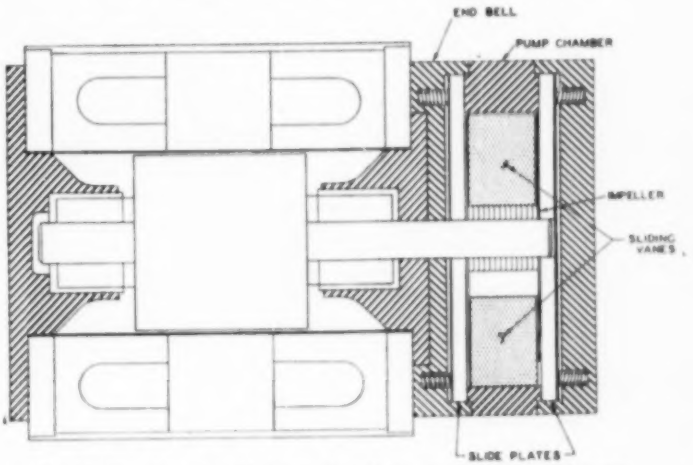


Fig. 12. Vane type of seal-less pump is used for gases, including radioactive.

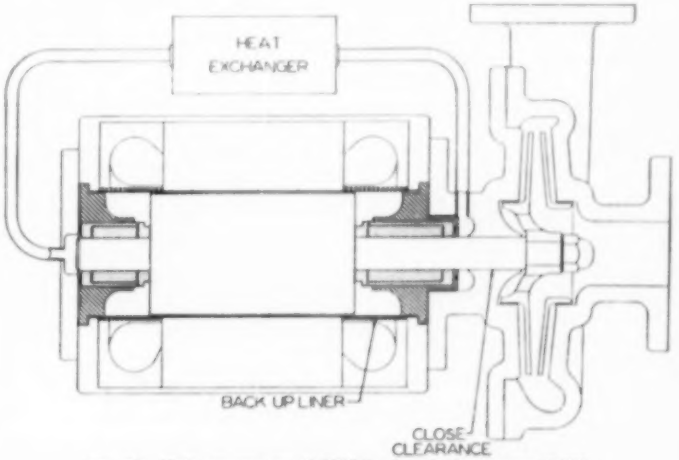


Fig. 13. High temperature (1,200° F. plus), high pressure (5,000 lb./sq.in. plus) pump. Cooling fluid is trapped in closed circuit, pumped by rotor vanes through circuit. Heat conduction minimized by narrow neck between volute and stator.

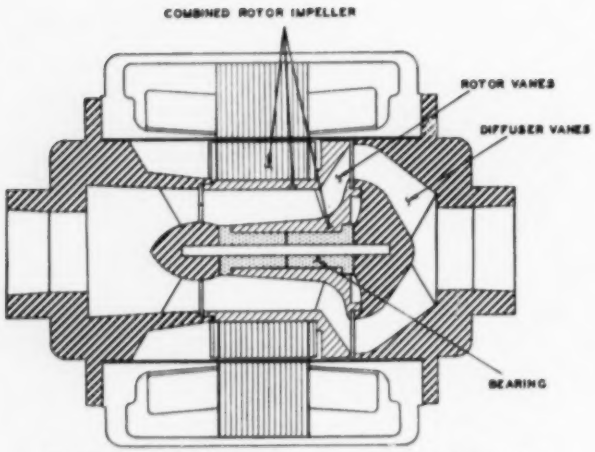


Fig. 13. Magnaflow. Essentially same as 1947 model. Manufactured under license by McDougall Co., Galt, Ontario, Canada.

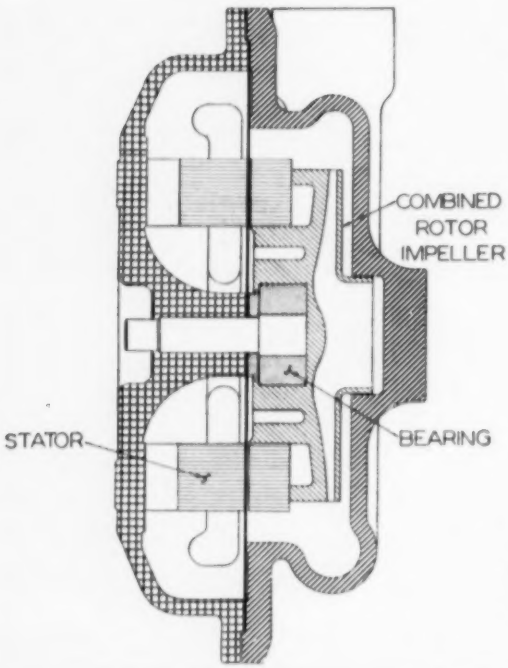


Fig. 16. Hermetik design produced under license by Leakproof Pumps, Inc., Bridgeport, Conn. Modified version sold to chemical and allied process industries as Chempump Model H.

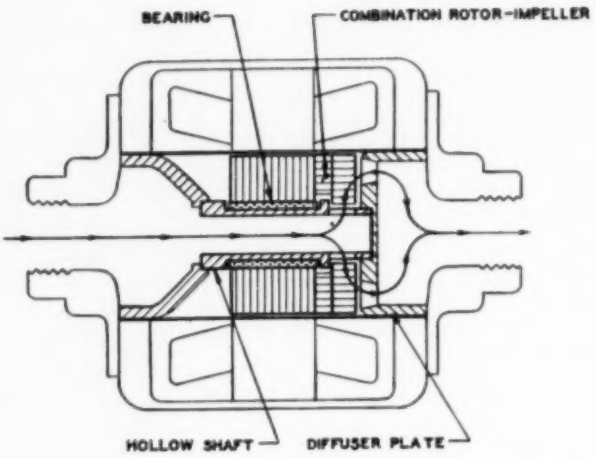


Fig. 14. Dynapump cross section. (Modified pump is sold to chemical and other process industries under name, Chempump Model E.)

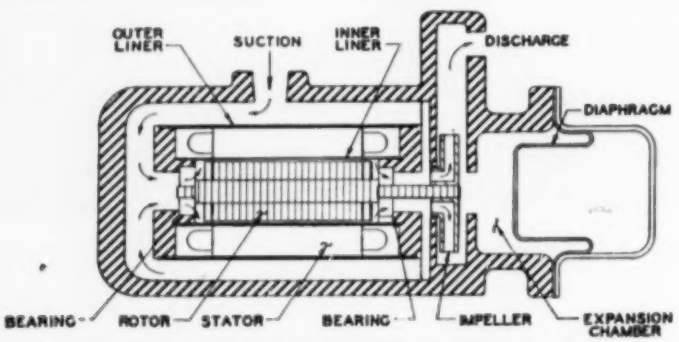


Fig. 17. Lightweight, 400-cycle-power seal-less pump designed for electronic cooling applications. Produced under license by Leakproof Pumps, Inc.

creased delivery rates over lower speed pumps.

SOME OTHER SEAL-LESS PUMP MODELS

Figures 11 through 17 show other seal-less pump designs that have been developed by the Chempump designers, and that are manufactured either by the Chempump Corporation or by other companies under license.

The double-ended unit shown in Figure 11 handles unusually high head or high volume applications and can be manifolded so that the two volutes work in series or parallel. When supplied for series operation, the first-stage impeller is made larger than the second stage, thereby maintaining an automatic thrust balance. Flow of fluid for cooling is obtained through orifice ports in each bearing housing.

Another unit, called the Dynapump, is shown in cross section in Figure 14. This pump has been received favorably by industry since its first appearance. In 300-series stainless steel it sells at a price lower than that of cast-iron construction in competitive units.

The Dynapump produces a relatively high head for its horsepower rating and can be mounted in any position. It has all the features connected with seal-less units. One great advantage of using stampings in its construction is that the unit may be constructed from expensive metals, such as titanium, Hastelloy, zirconium, etc. at a very low cost. This unit is produced under license by the Fostoria Pressed Steel Company, Fostoria, Ohio, and a modified version is sold to the chemical process industries under the name of Chempump Model E.

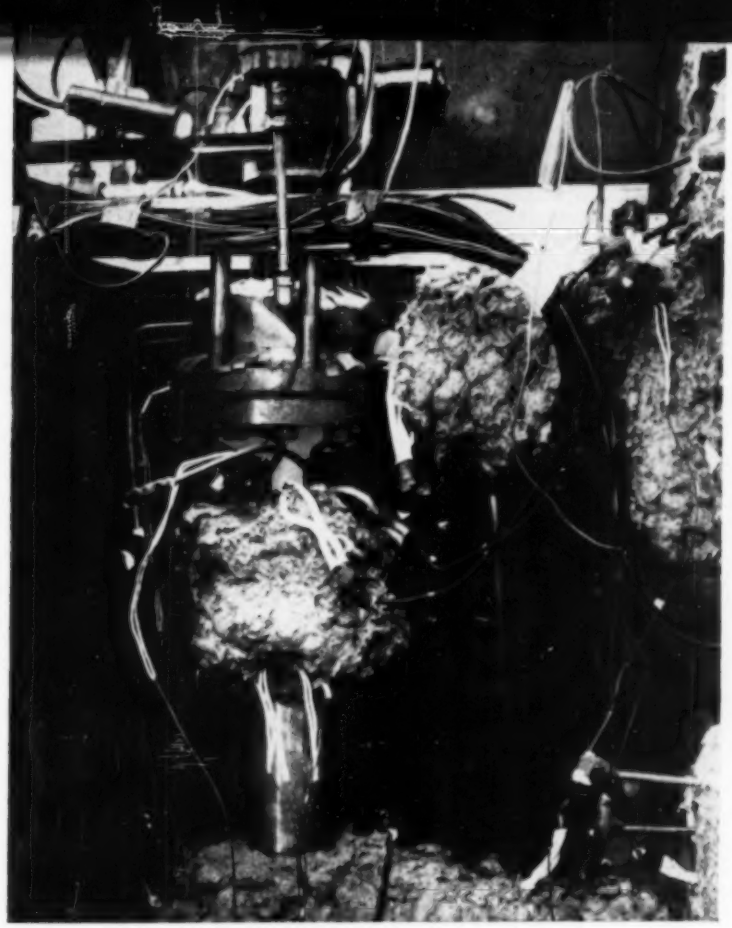


Fig. 7. Centrifugal Pump in Operation at 1500° F.

high-temperature centrifugal pumps

H. W. Savage and W. G. Cobb

Oak Ridge National Laboratory, Oak Ridge, Tennessee

High-temperature centrifugal pumps for liquids above 1,000° F. have presented some unusual structural, material, sealing, auxiliary, instrumentation, and reliability problems. These points are briefly discussed in this paper in connection with applications of liquid metals and fused salts encountered at Oak Ridge National Laboratory.

In the course of developing high-temperature processes the Oak Ridge National Laboratory has developed several high-temperature pumps for liquid metals and other fused heat-transfer media. Sodium, sodium-potassium alloy, lead, and fused salts with melting points approaching 1,000° F. are among the liquids which have been circulated at temperatures above 1,500° F. with centrifugal-type pumps. Continuous circulation has also been maintained with the liquids only a few degrees above their melting points.

The pumps which will be discussed have all been used in experimental loops wherein high velocity circulation was an important parameter. Some of these include the design of relatively small pumps capable of remote, reliable operation within the confines of channels into experimental reactors, such as the Low Intensity Training Reactor at Oak Ridge or the Materials Testing Reactor at Arco, Idaho. Pump capacity has increased from a few to several hundred gallons per minute, with heads as high as 100 ft. of pumped liquid.

In a truer sense of the word no pumping problem of a hydraulic nature existed, in that all the materials to be pumped have been true liquids, and in some respects have better physical properties than water. Problems do exist in the pumps, however, and the most important of these is the seal of the pump, i.e., maintenance of a sufficiently leak-tight system and at the same time provision of the motive power to the liquid.

The seal problem becomes difficult because

1. In nuclear systems it must be virtually absolute against leakage of radioactive liquids and gases.
2. It must be virtually absolute against the entrance of oxygen and water vapor to obviate chemical deterioration of the liquid and corrosion of the system.
3. It must be closely coupled with moving pump elements to avoid undue size of structure and/or excessive volumes for liquids and gases in the pump.
4. Cooling must be adequately maintained and controlled to prevent seal deterioration.

The lack of availability of bearing materials operable at these temperatures, as journal or other conventional-type bearings, makes it highly desirable to avoid internal guiding of rotating elements by means of bearings in the liquids. The high temperatures, to which the pump structural elements are subjected, cause reductions in strength of materials by more than an order of magnitude from those encountered in the conventional hot pump field; yet this strength factor does not cause pumps to be of unusual over-all size for their capacities even though the drive shaft usually becomes a larger size where subjected to the higher temperatures.

Controlled adequate heat removal to obtain thermal gradients in structural elements allows the use of near-conventional, mechanical elements in the parts removed from the high temperatures. High nickel and chromium content alloys resist corrosion, provide a comparatively high resistance to heat transfer enabling sharp thermal gradients to be taken, and also provide ample structural strength. The fact that sharp temperature gradients are obtainable

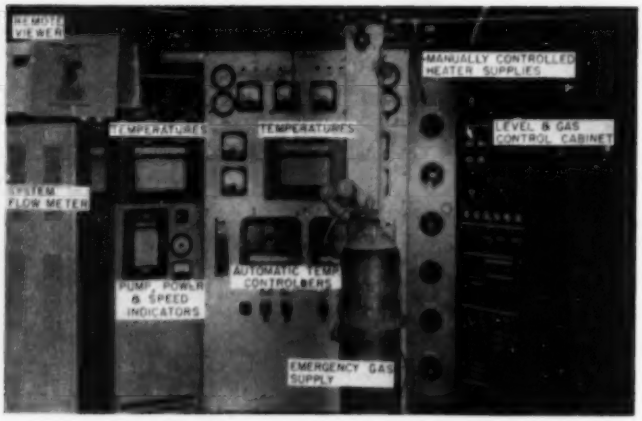


Fig. 1. Remote Control and Monitoring Equipment.

also dictates considerable caution to prevent disastrous thermal distortions.

Materials problems associated with these pumps are more difficult to resolve than those of normal pumps primarily because of mass-transfer possibilities due to thermal and solubility gradients, especially if more than one alloy is exposed to the liquid. This is one of the most difficult problems facing development of bearings and seals exposed to high-temperature liquids. Consequently, it was attempted to make certain that all parts exposed to the liquid would be of the same alloy.

Operationally a severe mechanical limitation arises because when associated with nuclear reactors and placed within the shielded volume, maintenance or repair becomes difficult, if not impossible. The operator has no personal contact with the machine—he can neither see nor hear it. True, he may provide himself with elaborate instrumentation, including television and high-fidelity audio systems, and indeed he does, and though these are admirable substitutes, their use complicates the operational picture, causes the watching of many more items, and requires development of interpretative skills for the diagnosing of difficulties.

Although the engineer provides himself with this wide variety of signaling equipment (Figure 1), he is faced with the dilemma of knowing that even if something goes wrong and he knows what it is, there may be little or nothing he can do about it, and, as a result of the trouble, the experiment may be finished. This condition places a high premium on reliability—indeed something very nearly approaching absolute reliability.

Absolute reliability of course can only be approached and then just for a given design; relative reliability can be determined only by many life tests of component parts and assemblies. This type of data is not yet available. However, experience to date indicates that several hundred hours of trouble-free operation at temperatures above 1,250° F. can usually be attained.

For the sake of comparison this analogy is used: 1,000 hr. of trouble-free operation at 1,500° F. is like driving an automobile continuously at 30 miles/hr. for 30,000 miles, and, discounting the gasoline stops, it is a rare vehicle that will make it. On the other hand, it is conventional practice in more normal pump applications to expect trouble-free continuous operation for many months.

The other usually available device to increase reliability by providing oneself with multiple pumps in parallel so that some can be spares or so that a single failure will not terminate the run appears feasible but has other limitations which arise from valving arangements required, volume of liquid tied up in the system, and, in some cases, mere space in which to put them.

Thus far quantity production of a given pump has been of minor interest since pumping requirements call for several unique designs.

The problems attacked have included

a. A 10-12 gal./min., 60-ft. head pump for general laboratory use.

b. A 125-gal./min., 60-ft. head, horizontal shaft centrifugal pump for liquid metals.

c. A 225-gal./min., 50-ft. head, vertical shaft centrifugal sump pump in which the sump was also the expansion tank of the system.

These pumps fall into two groups—those in which gas is sealed and those

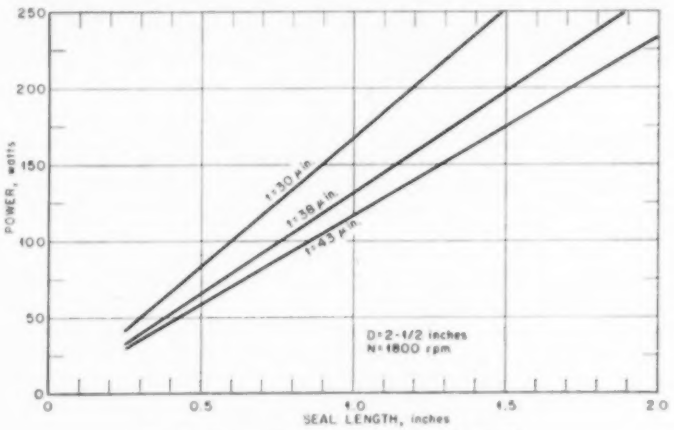


Fig. 2. Frozen No Seal—Power vs. Seal Length.

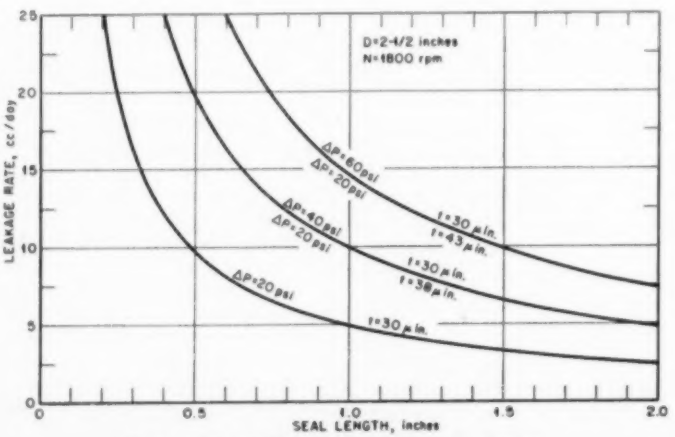


Fig. 3. Frozen No Seal—Leakage Rate vs. Seal Length

in which liquid is sealed. All have used an overhung shaft to eliminate the necessity of any internal bearing.

By far, the easier of these is sealing gas. The more difficult sealing of liquid can be accomplished in several ways, among which are seals in which the liquid can be allowed to solidify and form, in part at least, its own seal, applications, in which the liquid temperature is sufficiently low to permit the use of canned rotor drives, or the liquid has physical properties adequate to permit the use of electromagnetic pumps.

Frozen seals (or seals in which the liquid being pumped is made to form the closure by cooling to the solid state), in general, require more attention than gas seals because troubles will usually result in leakage of liquid. Additional operating parameters will also be encountered, some of which will need careful regulation, for example, seal coolant temperature. Also, since material being pumped is being frozen too, the seal acts as a cold trap for impurities; hence, quality control of the liquid becomes important.

Yet for metals which can be readily frozen and are soft, such as sodium or lead, the frozen seal works well and the parameters of design can be defined.

In theory the frozen seal acts like a self-healing journal bearing, without clearance, with the shaft riding in a very thin film of molten material. The power requirement due to friction will be proportional to length of seal and reciprocal of film thickness (Figure 2). Leakage (Figure 3) is theoretically possible and the rate can be predicted on the basis of flow of liquid through a very narrow annulus varying with the pressure drop. In practice one finds that it is important to control the pressure drop, and finds that leakage is sporadic and probably a function of the pickup of contaminants, such as oxides, which change the sealing temperatures.

Though the coolant problem is not severe, the reliability of the seal is dependent upon the cooling system, and, as mentioned before, the friction produced in the seal increases with increased cooling, and leakage increases with decreased cooling.

In practice one should isolate the seal from the effects of system thermal cycles (Figure 4). Sufficient control of temperature along the shaft should be obtained so that the body of liquid adjacent to the seal is just molten. The freezing zone should be as short as possible to keep the friction load down but of sufficient length to withstand momentary gradients. A seal of ¼-in. to ¾-in. length has been found to provide these features in this design.

The seal should be backed up with an inert gas blanket to prevent oxidation of the frozen material and to exclude moisture.

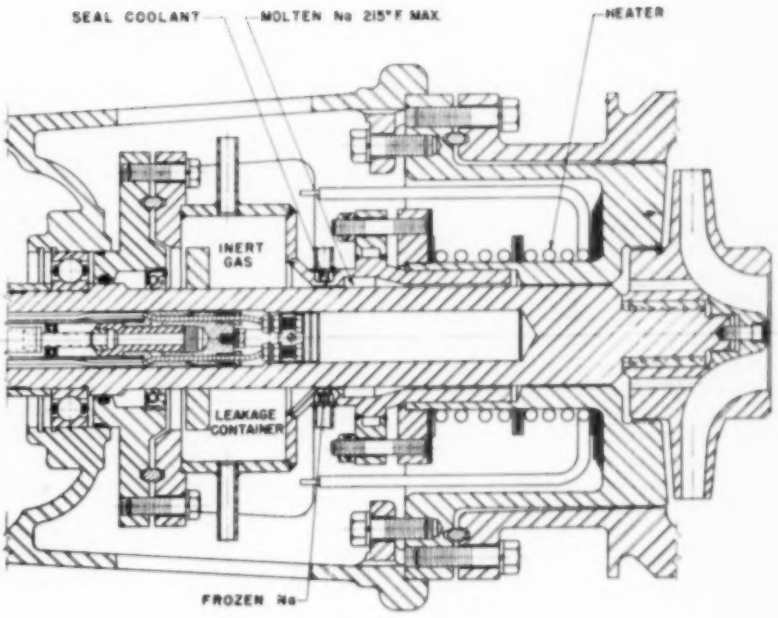


Fig. 4. Frozen Na Seal—Cross-Sectional View.

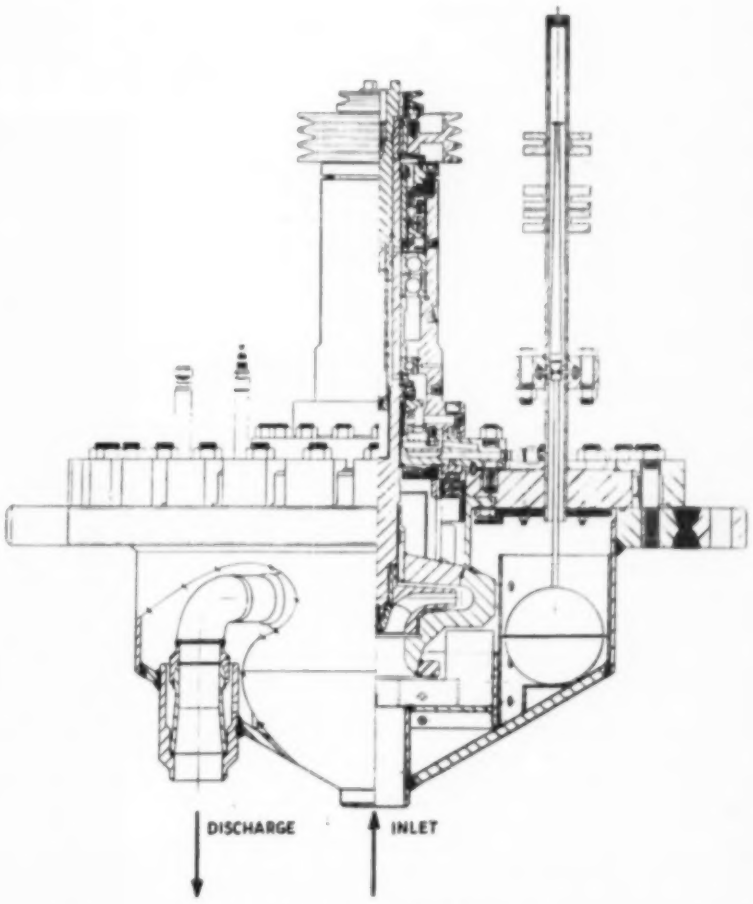


Fig. 5. Sump-Type Gas Sealed Pump.

Other problems encountered with a horizontal shaft pump of this type concern sufficient shaft diameter to provide stiffness against excessive deflections; control of seal and shaft temperatures for starting; provision for positive degassing for priming but still arranging for drainage; provision for heating and insulating for maintaining satisfactory alignment of parts under any imposed thermal regime, and for removing any seal leakage without interruption of operation.

The other pumps mentioned have been gas-sealed types, most of them incorporating face-type seals under near-zero pressure differential. The most successful of these is silver-impregnated graphite, oil lubricated, and running against flat-lapped hardened steel faces. These can be positioned at will but must be kept cool to preserve the lubricant, and should be free from random or high thermal gradients to preserve flatness of adjacent seal surfaces.

In the vertical-shaft sump pumps (Figure 5) the seal just mentioned is within a small gas-filled annulus which communicates with the pump sump only a few inches above the hot-liquid level in the sump. Cooling is provided for the shaft and for the stationary parts of the pump below and around the seal region. These cooling systems remove about 7 kw. of heat when the pump is operating at 1,400° F.

The bearing housing, shaft, seals, impeller, and discharge passages are conventional, but the sump is designed to take account of system volume changes due to temperature variations or liquid additions within limits. The pump degasses as long as sufficient head is maintained to by-pass some of the pumped liquid back into the sump through the annulus around the drive shaft.

Since the inlet of the pump is directly above the inlet to the sump, most of the gas entrained in the liquid enters the pump and is gradually eliminated with the by-pass leakage. Rotation of liquid in the sump is prevented by placing vertical vanes between the two inlets and around the casing.

Heat shielding is provided for the pump cover plate which supports all elements; stationary seals to be broken are provided by oval-ring metal gaskets, and the cover plate is clamped in place and is sealed by a flexible welded assembly since considerable differential expansion will occur.

Liquid levels in the tank are maintained by automatic devices responsive to probe or float signals which either increase or relieve the gas pressure in the sump tank. No constant bleed of gas through the tank is permitted in order to reduce the accumulation of condensate in gas lines.

The many functions that must be performed and controlled during the testing and operation of these pumps require a considerable array of auxiliary devices. These auxiliaries indeed at times pose almost as much of a problem as the main hot pump itself. Lubricants for bearings and seals are used also to maintain proper temperatures of these elements and must be supplied to the mechanism at definitely controlled temperatures so that high viscosity does not cause sufficient film resistance to allow elements to become overheated. When the pressure differential across the graphite seal is held essentially balanced (which is highly desirable from a gas leakage standpoint), the lubricant circulating system must be completely pressure tight. This requires auxiliary pumps (Figure 6) that have no seal leakage and are of comparable dependability with the hot pump. Cooling of the lubricant may be accomplished by exchanging the heat load to the surrounding atmosphere or the usually more convenient method of using a continuous flow of water. Any leakage of lubricant past the graphite face seal is captured on cooled surfaces and removed.

Conclusions

From the tests it can be concluded that troubles are mostly with the auxiliaries, bearings, and seals, and, that on none of these can one relax or compromise specifications. Especially tolerances in bearings must be met, and hardness and flatness specifications for the seals must be adhered to.

Referring briefly to the ancestor of these pumps, it should be stated that a sump-type pump (Figure 7) for laboratory use was the first one developed. This included an unshrouded centrifugal-type impeller which could be machined readily. Flow was downward through the sump bowl. The pump requires stilling vanes in the sump bowl to prevent vortexing beneath the impeller, and entry of liquid to the inlet eye must be substantially uniform around the periphery to prevent gassing.

Several pumps, such as those described here, have been built. They are sturdy, reliable for better than 1,000 hr., have been run at temperatures above 1,500° F., and the first one accumulated approximately 2,300 hr. of operation before it was retired without pump failure for metallurgical examination.

The conclusion is that centrifugal pumps can be run at 1,500° F. with considerable dependability by the use of either the sump-type pump with gas seal or a pump operated on the frozen seal principle.

(Presented at A.I.Ch.E. Ann Arbor meeting.)

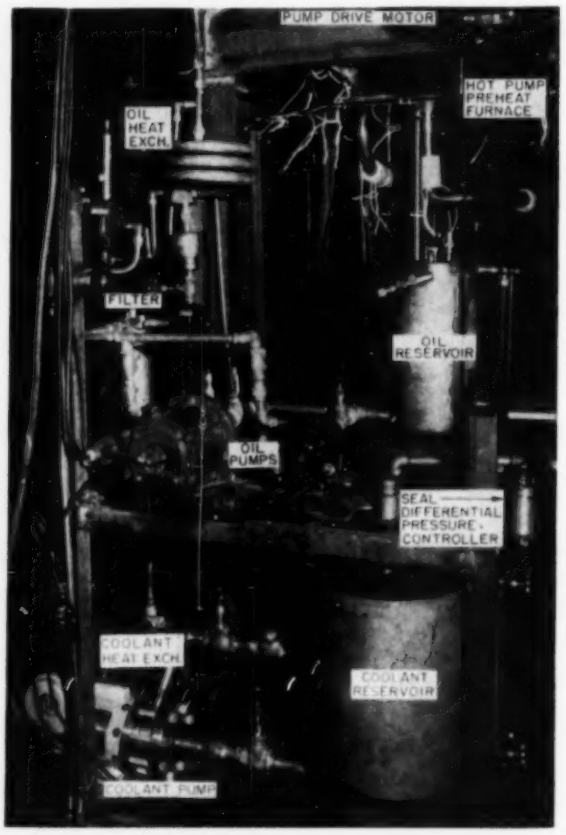


Fig. 6. Auxiliary Coolant Circulation Systems.

cocurrent liquid-gas flow in a pipe-line contactor

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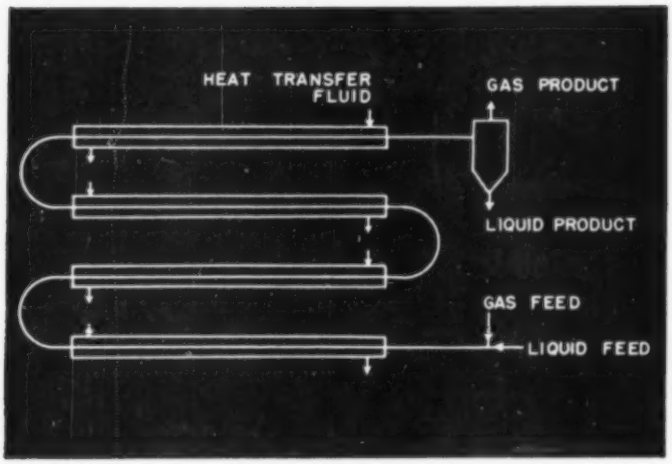

Fig. 1. Schematic diagram of a cocurrent pipe-line liquid-gas contactor.

Summary

The results of an experimental investigation on the isothermal flow of water-air and oil-air mixtures in a 1-in. cocurrent pipe-line contactor will be useful for the design of plant units.

The investigation was undertaken to provide basic data on flow pattern, pressure drop, and liquid holdup for the flow of liquid-gas mixtures in this type of equipment. Descriptions of the various possible flow patterns are presented. Visual observations were made of most of these patterns in the straight pipe and a return bend, and photographs of typical flow patterns are given. Limited data show the degree of entrainment of the liquid as spray by the gas core for annular flow.

The pressure-drop data for the straight pipe and the holdup data were compared with those given in the published literature. Pressure-drop data for the flow of liquid-gas mixtures have been extended to include the return bends and the inlet mixing tee.

Many chemical operations involving contacting of liquids and gases can be carried out advantageously and continuously in a cocurrent pipe-line liquid-gas contactor. This type of equipment, Figure 1, consists of a length of pipe into which are fed simultaneously through a tee a liquid stream and a gas stream. The streams, in contact with each other, then flow through the pipe and are finally separated by a cyclone type of separator.

During the past few years there has been a considerable amount of information published on the flow of liquid-gas mixtures in both straight horizontal pipes and straight vertical pipes; however, it was believed that additional experimental data were required for an understanding of the operation and for the design of cocurrent pipe-line liquid-gas contactors of the type shown in Figure 1. An experimental investigation was undertaken, therefore, to provide basic data on flow pattern in horizontal straight pipes and up-flow return bends, pressure drop in horizontal straight pipes and fittings, and liquid holdup in a small cocurrent pipe-line contactor.

* For Appendix A, containing the reduced experimental data, order document 4256 from A.D.I. Auxiliary Publications Photoduplication Service, Library of Congress, Washington 25, D. C., remitting $2.00 for microfilm or $3.75 for photoprints.

Experimental Equipment

A diagrammatic piping layout of the experimental cocurrent pipe-line contactor equipment is shown in Figure 1. Photographs of the equipment are presented in Figure 2.

The contactor consisted of four horizontal passes, each of 1-in. Schedule 40 stainless-steel pipe 16 ft. long. The horizontal lengths were connected by return bends of 7-in. radius and the flow was vertically upward through the return bends. In the study of the flow patterns, 18-in. lengths of 1-in. glass pipe were inserted at the inlet and the outlet of the contactor, and a 1-in. glass return bend with an 18-in. length of 1-in. glass pipe before and after the return bend was used to connect the first pass with the second pass. Pressure taps were located on top of each pass 6 in. (about 6 diam.) from each end of the pass; thus, the distance between taps for each pass was 15 ft. Thermocouples were inserted through the bottom of each pass at locations 2 in. (about 2 diam.) from each end of the pass.

Liquid and gas were fed simultaneously to the contactor through an ordinary threaded-type pipe tee with the liquid entering the run and the gas vertically downward through the branch. The liquid feed was pumped from a storage tank with a gear pump and was metered with rotameters. The liquid feed to the contactor was regulated by the flow through the pump by-pass, which was equipped with an air-operated con-

tral valve for automatic operation, an ordinary globe valve for manual operation, and a solenoid valve to open the by-pass line quickly during holdup measurements. The gas feed was taken from the plant (100-lb./sq.in. gauge) compressed air system, and metered with rotameters.

The two-phase stream discharging from the contactor was separated by means of a cyclone type of separator into a liquid stream which was returned to the storage tank and a gas stream which was discharged to atmosphere.

The temperature of the liquid in the storage tank was held constant by an automatically controlled, external, recirculating system, and the gas temperature was controlled automatically by an electric heater.

Pressure drops across each pass, across the four passes, and across the return bend between the first and the second pass were measured with manometers. Each manometer was equipped with an air purge and a trap to prevent the flowing liquid from entering the manometer lines. Temperatures were measured with pencil-type iron-constantan thermocouples.

Liquid holdup, that is, the amount of liquid within the contactor at any instant, was determined by closing simultaneously both the inlet and the discharge of the contactor with plug cocks. Plug cocks were used so that the flow would be unobstructed when the cocks were wide open. The operating levers of the two plug cocks were connected by a bar connected to a spring. With the plug cocks open, the spring was in tension, and, upon release of the bar, the two plug cocks would close quickly and simultaneously. The release mechanism also operated an electric switch which actuated solenoid valves to open the by-pass on the liquid-feed gear pump and to shut off the air feed. Liquid trapped in the contactor was then blown out through the separator and measured.

Experimental Procedure

Before flow data were obtained, the instruments were adjusted and calibrated. The passes were calibrated for the isothermal single-phase flow of water, S.A.E.-10 oil, and air; that is, the pressure drops across each pass, pressure drops across the first return bend, fluid pressure and temperature, and room temperature readings were obtained for various flow rates of each fluid at or near room temperature. From these data the friction factor vs. Reynolds number plot could be made for each contacting section. This plot was necessary for the computation of the single-phase pressure drops required in the two-phase correlation.

Data were obtained for the isothermal two-phase flow of water-air and S.A.E.-10 oil-air mixtures. For various constant liquid rates and a range of air rates at or near room temperature, the liquid holdup, pressure drop across each pass, pressure drop across one return bend, fluid pressure and temperature, and room temperature were measured. The pressure-drop data for any one run were within about $\pm 10\%$ when compared with check runs, and the liquid holdup data were within about $\pm 5\%$; however, the majority of the data were well within these limits of reproducibility. The reduced experimental data are presented in Appendix A.

The technique for measuring the liquid holdup was as follows. A determination of the amount of water lost by entrainment and by wetting of the inner pipe walls, when the holdup volume was blown out through the separator, was made by drying the pipe walls with air, then adding a known weight of water to the inlet of the first pass, and finally collecting the water blown out through the separator. This loss was determined to be 0.12 ± 0.02 lb. water. The total amount of water in the contactor with single-phase flow was determined by operating the contactor with single-phase flow of water, tripping the quick-closing valve mechanism, and blowing the water trapped in the contactor through the separator. The amount of water collected from the separator plus the loss mentioned above was the total amount of water in the contactor for single-phase flow. The total weight of oil in the contactor for single-phase flow was computed by multiplying the total weight of water, determined above, by the ratio of the density of oil to that of water. The loss of oil by entrainment or by wetting of the pipe walls was determined by operating the contactor with single-phase flow of oil, tripping the quick-closing valve mechanism, blowing the oil trapped in the contactor through the separator, and finally, obtaining the difference between the foregoing computed total amount of oil in the contactor and the weight of oil collected from the separator. This loss was 0.5 ± 0.1 lb. oil. To obtain two-phase flow liquid holdup measurements, the manometer lines were closed by valves at the pressure tap locations, the quick-closing valve mechanism was tripped, and the liquid entrapped was blown out through the separator and collected. The two-phase flow liquid holdup was simply the ratio of the amount collected plus the loss to the total amount in the contactor at any time for single-phase flow.

Photographs of typical flow patterns were obtained by using the glass observation sections. Diffused light was passed through one side of the section and photographs were taken from the opposite side with an exposure time of 1/1,000 sec.

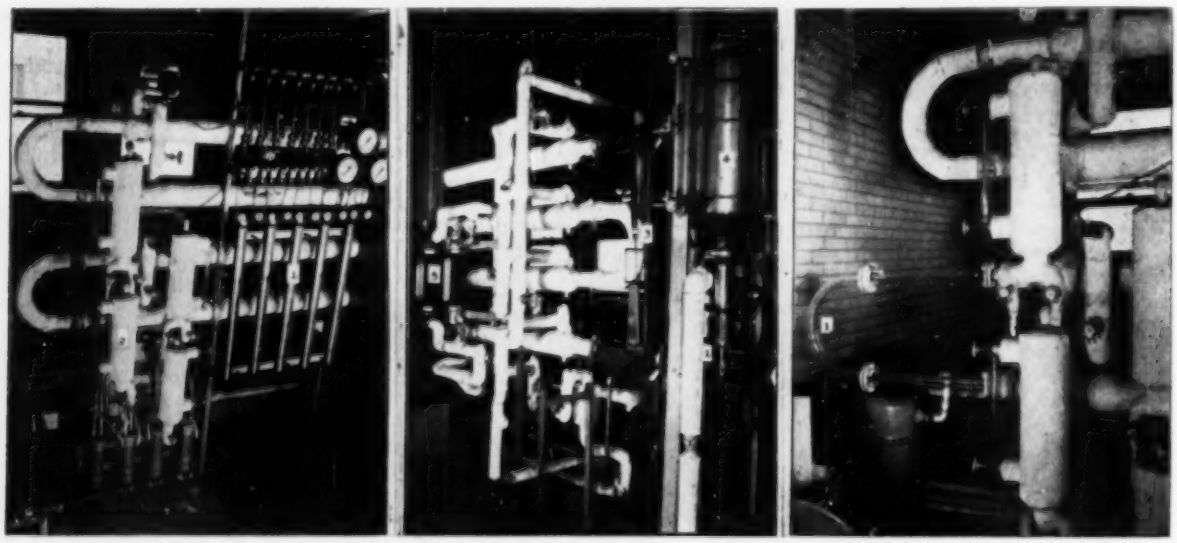

Fig. 2. Equipment photographs. Cocurrent pipe-line liquid-gas contactor.

(A) Left side view of passes
1. Manometer system
2. Jacket condensate metering system

(B) Right side view of passes
1. Inlet tee
2. Glass observation sections
3. Quick-closing valve system
4. Separator
5. Jacket cooling-water rotameters

(C) Close-up of left side of passes
1. Glass return bend
2. Glass sections before and after bend

Discussion of Results

In the cocurrent flow of a liquid and a gas there are four possible flow mechanisms or combinations of viscous and turbulent flow conditions; liquid turbulent and gas turbulent, liquid turbulent and gas viscous, liquid viscous and gas turbulent, liquid viscous and gas viscous. However, only two, namely, liquid turbulent and gas turbulent, and liquid viscous and gas turbulent, have widespread application in cocurrent pipe-line contactors within the chemical industry. In addition, for each combination there may be several flow patterns depending upon the liquid and gas flow rates and also upon the type of inlet.

Flow Pattern

The following general types of flow have been observed in straight horizontal pipes by the author and by other investigators (*2, 8*). If in Figure 3, there were a horizontal pipe with liquid flowing so as to fill the pipe, the types of flow that occur as gas is added in increasing amounts would be

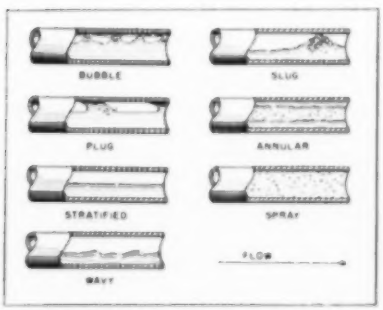

Fig. 3. Flow pattern sketches.

a. bubble flow—flow in which bubbles of gas move along the upper part of the pipe at approximately the same velocity as the liquid,

b. plug flow—flow in which alternate plugs of liquid and gas move along the upper part of the pipe,

c. stratified flow—flow in which the liquid flows along the bottom of the pipe and the gas flows above it over a smooth liquid-gas interface,

d. wavy flow—flow which is similar to stratified flow except that the gas moves at a higher velocity and the interface is disturbed by waves traveling in the direction of flow,

e. slug flow—flow in which a wave is picked up periodically by the more rapidly moving gas to form a frothy slug which passes through the pipe at a much greater velocity than the average liquid velocity,

f. annular flow—flow in which the liquid flows in a film around the inside wall of the pipe and the gas flows at a high velocity as a central core,

g. spray flow—flow in which most or nearly all of the liquid is entrained as spray by the gas.

In wavy flow of water-air and oil-air mixtures, the relative velocity of the air with respect to the liquid was of the order of 10 to 15 ft./sec. These data are in agreement with those of other investigators (*3*).

It should be emphasized that in slug flow the slugs can cause severe and, at times, dangerous vibrations in the equipment because of the impact of the slugs against the return bends.

Annular flow occurs with water-air and oil-air mixtures at superficial air velocities of about 20 to 70 ft./sec. depending upon the liquid rate. Observations indicated that a portion of the liquid is entrained as a spray by the central gas core. A few determinations were made of the amount of entrainment by obtaining a sample from the central portion of the pipe with a sampling tube, which occupied about 35% of the pipe cross-sectional area, and then computing the entrainment for the total pipe cross section assuming that the spray concentration was uniform over the entire cross section. Table 1 gives the results of these measurements.

Photographs of actual flow patterns in the straight pipe sections of the contactor are shown in Figure 4.

In the majority of the published articles, very little mention is made of the flow patterns. Regions of various flow patterns in terms of the weight rates of flow of water and air for flow in straight horizontal lengths of pipe have been defined by Bergelin and Gazley (*2*) for 1-in. pipe and by Johnson and Abou-Sabe (*5*) for 0.870-in. I.D. pipe. Kosterin (*6*) defined the regions of various flow patterns against the volumetric flow fraction of the gas and

Table 1.—Entrainment in Annular Flow

V_L ft./sec.	V_G ft./sec.	$(N_{Re})_L$	$(N_{Re})_G$	R_L	Entrainment %
Water-Air					
0.12	67.3	946	43,800	0.045	5.1
0.12	93.2	946	65,900	0.038	17.9
0.12	109.8	965	96,300	0.029	36.9
0.37	81.0	3,020	65,600	0.060	25.4
S.A.E. 10 Oil-Air					
0.087	52.6	8.5	53,100	0.088	18.9

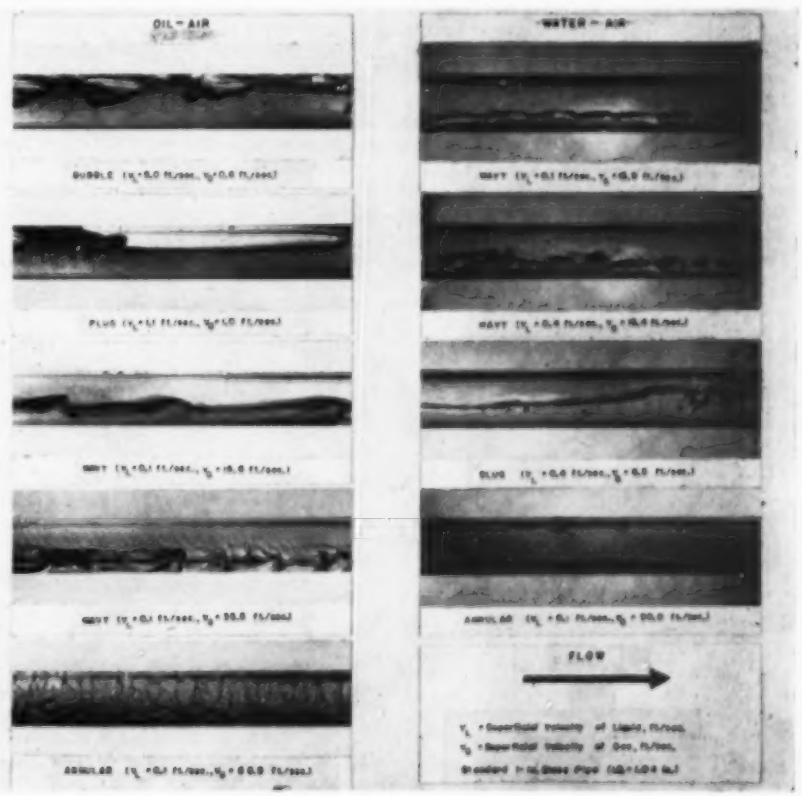

Fig. 4. Photographs of flow in a straight pipe.

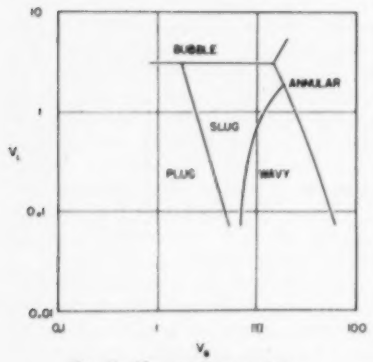

Fig. 5. Flow pattern regions.
1.042-in. I.D. pipe.
Water-air and S.A.E. 10 oil-air.

the superficial mixture velocity for the flow of water-air mixtures in 1-, 2-, 3-, and 4-in. horizontal pipes. The maximum superficial mixture velocities studied were about 45 ft./sec. Because of equipment limitations, Kosterin was able to define the annular flow region only for the 1-in. pipe. Hughes, Evans, and Sternling (*4*) in their Figure 3 combine the four plots on flow pattern presented by Kosterin (*6*) together with the results of incidental observations reported by other investigators. An investigation of the liquid film in annular flow was made by Abramson (*1*).

Figure 5 shows the regions of flow patterns observed in the present study of water-air and oil-air mixtures. The regions, shown as a function of liquid and gas superficial velocities, are dependent upon the interpretation of the investigator. The flow patterns obtained in the contactor did not occur in the same order as described above, because of the effect of up-flow return bends on the flow in the straight lengths of pipe. Stratified flow was not possible with the return bend at the end of the first pass; however, stratified flow was obtained after removal of the return bend and with a free discharge of the first pass. Thus the return bend would also have an effect upon the other types of flow, except possibly annular and spray. An up-flow return bend preceding a pass caused slugging in that pass. The experimental data indicated that the transition from wavy flow to annular flow for the water-air mixtures may occur for air velocities slightly higher than those for the flow of oil-air mixtures, and for the flow of water-air mixtures, this transition occurred at air flow rates two or three times as great as those reported by Bergelin and Gazley (*2*). For superficial liquid velocities greater than 3 ft./sec., it was difficult to distinguish by visual observation annular flow from bubble flow consisting of many fine bubbles dispersed throughout the liquid.

Photographs are shown in Figure 6 of flow patterns of oil-air mixtures in return bends with flow vertically upward in the bend. Annular flow was observed to be stable, and a thicker film of liquid was present along the inside radius than the outside.

Pressure Drop

STRAIGHT PIPE

For the isothermal single-phase flow of water and of air, the friction factors for turbulent flow were about 8% greater than those for smooth pipe (*9*), and about 8% less than those for commercial pipe (9). The reason for the friction factors being greater than those for smooth pipe and less than those for commercial pipe was that the inside surface of the contactor pipe was smooth and wavy. The friction factors for viscous flow, checked with the use of oil, were 10% higher than the accepted values; this was attributed to the additional pressure drop caused by the manometer purge air flowing as bubbles (bubble flow) with the oil.

A comparison was made of the pressure-drop data of the isothermal two-phase flow of water and air and of oil and air with the pressure drop predicted by the semiempirical correlation of Lockhart and Martinelli (*7*). The correlation is based on the following assumptions:

1. **The static pressure drop for the liquid phase equals the static pressure drop for the gas phase regardless of the flow pattern, provided that an appreciable radial static pressure difference does not exist.**
2. **The volume occupied by the liquid plus the volume occupied by the gas at any instant equals the total volume of the pipe.**

Assumption 1 implies that the flow pattern does not change along the pipe length, and thus plug, stratified, wavy, and slug flows are not considered. The derivation and discussion of the necessary parameters used in the correlation are given by Lockhart and Martinelli (*7*).

Briefly, the basis of the correlation is that the two-phase pressure drop is equal to the single-phase pressure drop for either component multiplied by a factor which was found to be a function of the ratio of the single-phase pressure drop of the liquid to that of the gas; that is,

$$(\Delta p/\Delta L)_{TP} = \phi_L^2(\Delta p/\Delta L)_L, \qquad (1)$$

$$(\Delta p/\Delta L)_{TP} = \phi_G^2(\Delta p/L)_G \qquad (2)$$

where

$$\phi_L^2 = F_1(X), \qquad (3)$$

$$\phi_G^2 = F_2(X), \qquad (4)$$

$$X^2 = (\Delta p/\Delta L)_L/(\Delta p/\Delta L)_G. \qquad (5)$$

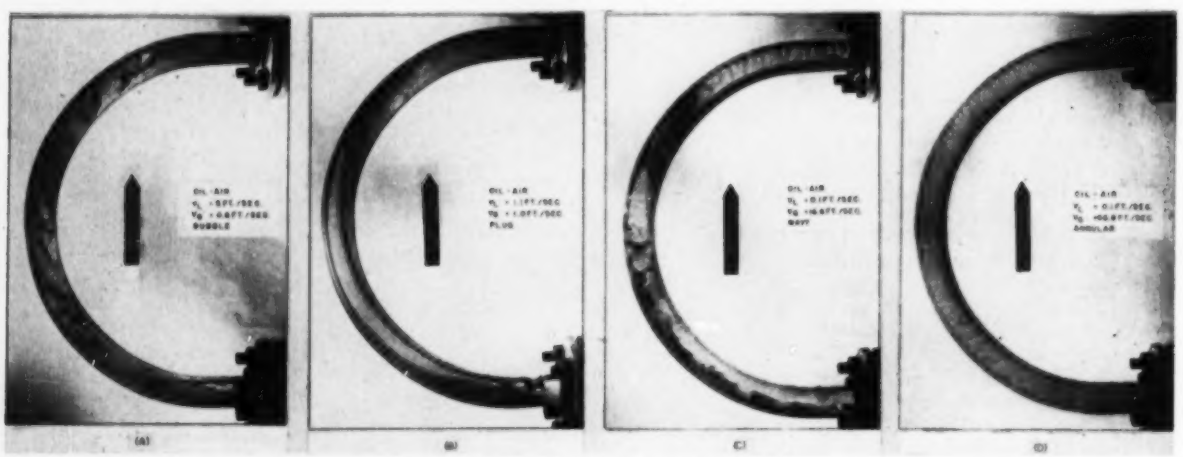

Fig. 6. Photographs of flow in a return bend.
V_L = superficial velocity of liquid, ft./sec. V_G = superficial velocity of gas, ft./sec.
S.A.E. 10 oil — Standard 1-in. glass pipe (I.D. = 1.04 in.) — Room temperature

and

$$(\Delta p/\Delta L)_L = \rho_L(4f_L/D)(V_L^2/2g_c) \quad (6)$$

$$(\Delta p/\Delta L)_G = \rho_G(4f_G/D)(V_G^2/2g_c). \quad (7)$$

It should be noted that

$$\phi_G^2 = X^2\phi_L^2 \quad (8)$$

and that V_L and V_G are the superficial velocities of the liquid and the gas, respectively, based on the full cross-sectional area of the pipe; that is,

$$V_L = q_L/A. \quad (9)$$

$$V_G = q_G/A. \quad (10)$$

Separate correlating curves of ϕ^2 vs. X are required for each flow mechanism. Lockhart and Martinelli (7) correlate their data within about ±50%.

The transition criterion between viscous flow and turbulent flow is not definitely known. A tentative criterion has been given by Lockhart and Martinelli (7). However, the transition criterion between viscous flow and turbulent flow used in the present studies was the same as that for single-phase flow; that is, the flow was considered viscous for $N_{Re}<2100$ and turbulent for $N_{Re}\geq 2100$, where N_{Re}, the Reynolds number, was based on the superficial velocity.

Figure 7 shows the experimental results for the factor ϕ^2 compared with the predicted values for the flow mechanism, where both the liquid and the gas were in turbulent flow. The experimental values of ϕ^2 for the first pass were within +20% and −30% of the predicted values. In general, annular flow produced pressure drops greater than the predicted. Pressure drops smaller than the predicted were obtained for bubble, slug, and wavy flows. For any one run, the pressure drop a pass increased, in general, with the number of the pass; the first pass produced the lowest pressure drop and the fourth, or last, pass gave the highest pressure drop. This increase in pressure drop with pass was probably due to the effect of the bend on the flow pattern.

Data for ϕ^2 for the flow mechanism where the liquid was in viscous flow and the gas was in turbulent flow are compared with the predicted values in Figure 8. For the flow of oil-air mixtures, the data were within +43% and −36% of the predicted for annular flow, and for wavy flow the actual pressure drops were about 60% less than the predicted. The few data for the flow of water-air mixtures for the first pass were within +42% and −25% of the predicted. The flow pattern was annular for the flow where the values were greater than predicted and was slug and wavy where the values were lower.

Pressure-drop data for the other two-flow mechanisms, i.e. liquid-turbulent and gas-viscous and liquid-and-gas-viscous mechanisms, were too limited for valid comparison with the predicted values. For the liquid-turbulent and gas-viscous mechanism, a few pressure-drop data were obtained with the flow of water-air mixtures in the region $30<X<80$. The air was flowing as bubbles throughout the upper half of the pipe cross section and the experimental pressure drops for the first pass were within ±20% of the predicted. A few presure-drop data were also obtained for the flow of oil-air mixtures where the flow of both liquid and gas were viscous. These data were in the region $10<X<210$ and the flow patterns were of the bubble and plug types. For bubble flow, the experimental values of the pressure drop were up to 17% above the predicted and for plug flow, the experimental values were up to 32% below the predicted.

In general, the correlations for both liquid and gas turbulent, and liquid viscous and gas turbulent gave low values of the predicted pressure drop for annular flow, high values of the predicted pressure drop for stratified and wavy flows, and reasonable values of the predicted pressure drop for bubble flow. However, on the whole, the experimental data were within the accuracy of the correlation, and therefore the correlation can be used to predict the pressure drop for cocurrent liquid-gas pipe-line contactors if the deviations reported above are taken into account.

Visual observations showed the liquid in the contactor in a high degree of agitation. The power, expressed as hp. per 1,000 gal. of liquid holdup, expended in agitating the liquid was computed for representative runs for annular flow by

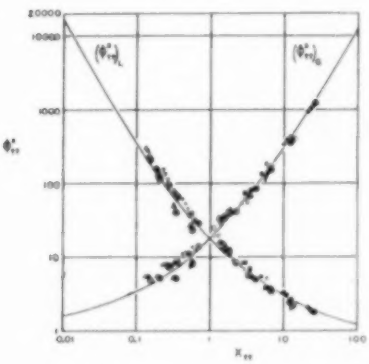

Fig. 7. Two-phase pressure-drop correlation. Liquid turbulent, gas turbulent.

Curves	Nominal Pipe diam., in. Capillaries, ½ & 1	$(N_{Re})_L$	$(N_{Re})_G$	System oil-air water-air	Source Lockhart & Martinelli
△	1	3,040– 3,320	21,700–65,000	water-air	Author
▽	1	5,790– 5,930	21,900–65,300	water-air	Author
+	1	10,200	43,800–66,000	water-air	Author
×	1	26,300	3,620–40,400	water-air	Author
◇	1	33,200	41,700–55,600	water-air	Author
●	1	58,300–59,100	3,530– 8,680	water-air	Author
■	1	64,700	21,100–39,100	water-air	Author

Note: For each run there are four points, one for each pass. The point for the first pass is encircled ○.

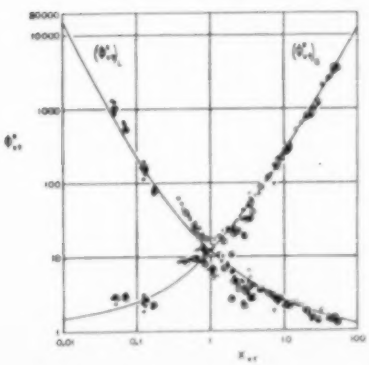

Fig. 8. Two-phase pressure-drop correlation. Liquid viscous, gas turbulent.

Curves	Nominal Pipe diam., in. Capillaries, ½ & 1	$(N_{Re})_L$	$(N_{Re})_G$	System oil-air water-air	Source Lockhart & Martinelli
○	1	5– 7	5,000–75,000	oil #-air	Author
△	1	14– 18	11,600–70,700	oil #-air	Author
▽	1	54– 59	7,180–74,200	oil #-air	Author
+	1	92– 99	2,890–74,600	oil #-air	Author
×	1	122– 128	2,880–74,200	oil #-air	Author
□	1	253– 258	2,830–21,800	oil #-air	Author
◇	1	424	5,020	oil #-air	Author
●	1	1,040–1,150	14,200–65,200	water-air	Author
			# S.A.E.	10 oil	

Note: For each run there are four points, one for each pass. The point for the first pass is encircled ○.

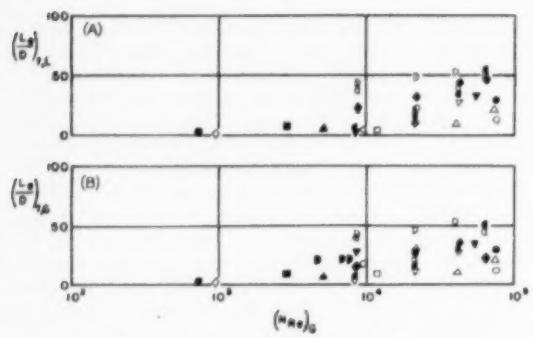

Fig. 9. Pressure drop across inlet tee.

	Pipe diam. (in.)	$(N_{Re})_L$	System	Source
○	1.042	7	oil #-air	Author
□	1.042	20	oil #-air	Author
△	1.042	62	oil #-air	Author
●	1.042	134	oil #-air	Author
■	1.042	285	oil #-air	Author
▲	1.042	460	oil #-air	Author
◇	1.042	524	oil #-air	Author
◆	1.042	1,070–1,110	water-air	Author
◑	1.042	3,480–3,510	water-air	Author
◖	1.042	6,420–6,480	water-air	Author
▽	1.042	12,600	water-air	Author
▼	1.042	32,700	water-air	Author
D	1.042	64,700	water-air	Author
◗	0.5	1,480– 1,610	water-air	Zannoni
			# S.A.E. 10 oil	

considering that the excess of pressure drop over that which would be required for the single-phase flow of the gas was expended in agitation. The results of these computations are given in Table 2. For conventional apparatus, 4 to 50 hp./1,000 gal. is classified as intense agitation; thus, very intense agitation is obtained in a cocurrent pipe-line liquid-gas contactor.

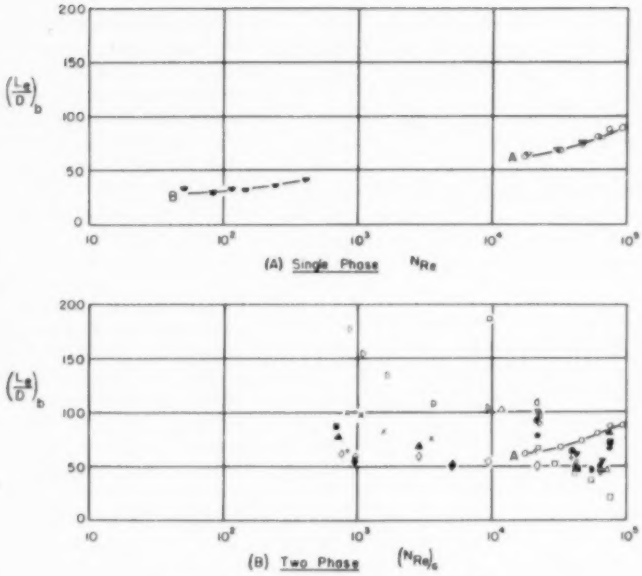

Fig. 10. Pressure drop across return bend.

	$(N_{Re})_L$	System
○	Curve A ○	Air (single phase)
□	5– 7	oil #-air
△	14– 18	oil #-air
●	54– 59	oil #-air
■	92– 96	oil #-air
▲	122–126	oil #-air
◇	253–286	oil #-air
◆	424–485	oil #-air
◑	982– 1,040	water-air
◖	3,040– 3,320	water-air
▽	5,790– 5,930	water-air
▼	10,200	water-air
D	26,300	water-air
◗	33,200	water-air
×	58,300–59,100	water-air
+	64,700–66,400	water-air
▭	(A) Curve A	water (single phase)
▬	(A) Curve B	oil # (single phase)
		# S.A.E. 10 oil

INLET

The pressure drop due to the inlet tee is given in Figure 9 as the equivalent length of straight pipe in pipe diameters vs. the superficial gas Reynolds number. Values of the superficial liquid Reynolds number are listed in the legend. The equivalent length as given excludes that for straight pipe friction; in other words, this equivalent length is a measure of the pressure drop due to mixing. (A) of Figure 9 is the pressure drop across the liquid side (on-run) of the tee, and (B) is that for the gas side (branch). With increasing gas flow rate at a constant liquid flow rate, the pressure drop increased; however, the effect of liquid flow rate was not conclusive, though, in general, the pressure drop increased for increasing liquid flow rate at a constant gas flow rate. Some of the pressure-drop data reported by Zannoni (*10*) for a ½-in. tee were analyzed and compared with the present data in (B) of Figure 9. There was fair agreement between the two sets of data. These values apply only to a 1-in. standard threaded-type pipe tee with the liquid entering the run and the gas entering vertically downward through the branch; however, they can serve as a guide for other sizes and configurations.

RETURN BEND

The pressure drop due to the 1-in. return bend of 7-in. radius with upward flow is given in Figure 10 as the equivalent length of straight pipe expressed in pipe diameters. These data are subject to error as the pressure taps were only six pipe diameters before and after the bend. The measured pressure drops

Table 2.—Power Consumed in Agitation

V_L (ft./sec.)	$(N_{Re})_L$	V_G (ft./sec.) Inlet	Outlet	$(N_{Re})_G$	$(\Delta p/\Delta l)_{TP}$ (lb./sq. in.)/ft.	ϕ_G^2	R_L	P (hp./ 1,000 gal.)
water-air								
0.17	1,505	38.8	41.0	21,700	0.0103	2.6	0.068	130
0.17	1,505	92.5	117.0	65,200	0.0706	2.8	0.038	4,300
1.25	10,180	57.4	91.2	66,000	0.199	11.4	0.123	3,600
S.A.E.-10 oil-air								
0.64	53.9	36.0	37.1	21,900	0.107	33.9	0.333	336
0.64	53.9	37.6	61.8	40,000	0.149	23.8	0.250	760
0.64	54.6	50.8	97.0	74,200	0.333	18.5	0.171	4,230
3.05	258	13.0	28.0	21,800	0.420	229.0	0.456	570

were corrected to allow for the pressure drop in the straight pipe between the bend and the pressure tap.

In (A) of Figure 10 the equivalent length as a function of the Reynolds number is given for the single-phase flow. These values include the static head correction. In (B) of Figure 10 the equivalent length as a function of the superficial gas Reynolds number with the superficial liquid Reynolds number as a parameter is presented for two-phase flow. Static head corrections were not applied, except for the zero rate of liquid flow, because of difficulty in estimating the static head. For the annular flow, $(N_{Re})_G > 40{,}000$, of water-air mixtures, the equivalent length appears to be approximately constant at a value of about fifty pipe diameters; however, the oil-air data were not as consistent as the water-air data. Although these values apply only to the specific return bend investigated, they can serve as a guide for return bends of other diameters and radii of curvature.

Holdup

Lockhart and Martinelli (*7*) postulated that the liquid and gas holdups, i.e., the fraction of the pipe volume occupied by that phase, were functions of the parameter X. Thus,

$$R_L = F_3(X) \qquad (13)$$

$$R_G = F_4(X) \qquad (14)$$

where $$R_L + R_G = 1. \qquad (15)$$

They found that their data for all flow mechanisms could be correlated within ±50% of a single curve.

The experimental holdup results reported herein represent the average holdup over the total length of the contactor including the return bends. The volume of the return bends was about 9% of the total volume of the pipe-line contactor.

In Figure 11a the liquid holdup results are presented for the flow of water-air mixtures. Curve A is the liquid holdup as predicted by the correlation of Lockhart and Martinelli. The majority of the water holdup results were within 0 to −34% of the predicted curve. An approximate division of the data according to the flow pattern is as follows: for $0.05 < X < 0.5$ the flow was annular; for $0.5 < X < 5$, annular, wavy, slug; for $5 < X < 70$, bubble flow. A separate curve can be passed through the points for each constant water flow rate. A few of the data are replotted in Figure 11b to show the trend of the holdup with water flow rate and with air flow rate. For annular flow the holdup decreased with increased water flow rate based on the correlation shown in Figure 11b. The data for any constant water flow rate did not lie on a smooth curve similar to that predicted by Lockhart and Martinelli, but exhibited a transition region, which occurred, in general, where the flow was slug, wavy, and beginning annular.

Liquid holdup data obtained by Gazley (*3*) for the stratified flow of water and air in a 2-in. pipe, were within ±50% of the predicted values. For each water flow rate a separate curve was obtained similar in shape to the curves shown in Figure 11b. Gazley's data covered a range of X from 0.2 to 15; and, since, in his case, these values corresponded to stratified flow, there was no general agreement with the data in Figure 11a as to flow pattern. The holdup data for the nonisothermal flow of water-air mixtures reported by Johnson and Abou-Sabe (*5*) showed a trend for low water rates similar to the trends in Figure 11b.

The liquid holdup results for the flow of oil-air mixtures in this investigation are shown in Figure 12. These results were within ±15% of a smooth curve, Curve B, but were from 14 to 54% below those predicted by the correlation, Curve A. Neither the transition region nor the effect of liquid flow rate, as shown in Figure 11b, was observed. Annular flow existed for $0.4 < X < 2$, annular and wavy for $2 < X < 10$, plug and slug for $10 < X < 100$, and bubble for $X > 100$.

In general, the experimental results were within the accuracy of correlation as reported by Lockhart and Martinelli. The results are more characteristic of

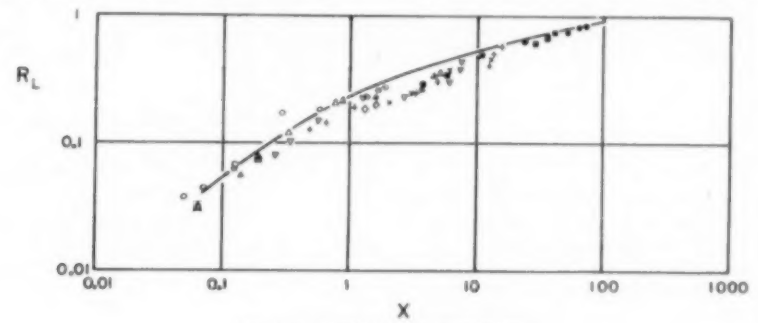

Fig. 11a. Liquid holdup correlation. (water-air)

Curve	A	Nominal Pipe diam., in. Capillaries,	$(N_{Re})_L$	$(N_{Re})_G$	System	Source
		½ & 1	1.1–124,000	7–86,000	oil-air water-air	Lockhart & Martinelli
○		1	967– 1,110	807–65,200*	water-air	Author
△		1	3,040– 3,320	806–65,000*	water-air	Author
▽		1	5,790– 6,000	820–65,300*	water-air	Author
+		1	10,000–10,200	840–66,000*	water-air	Author
×		1	26,300	835–40,350*	water-air	Author
□		1	28,500	825– 1,610*	water-air	Author
◇		1	33,200	41,700–55,600*	water-air	Author
●		1	58,300–59,100	815– 8,680*	water-air	Author
■		1	64,700–66,400	8,380–39,100*	water-air	Author

* × decrease as $(N_{Re})_G$ increases.

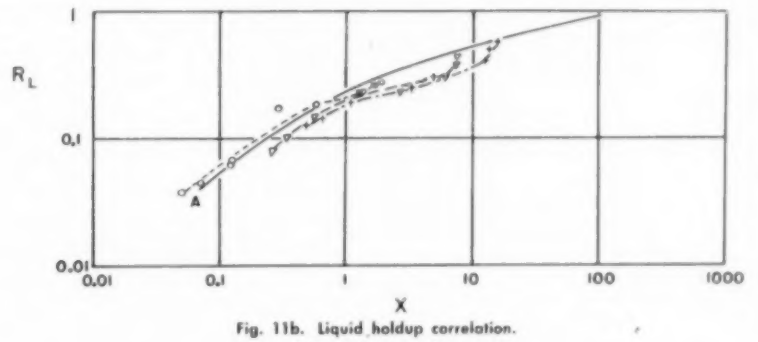

Fig. 11b. Liquid holdup correlation. Effect of liquid flow rate (water-air)

Curve	A	Nominal Pipe diam., in. Capillaries,	$(N_{Re})_L$	$(N_{Re})_G$	System	Source
		½ & 1	1.1–124,000	7–86,000	oil-air water-air	Lockhart & Martinelli
○		1	967– 1,110	807–65,200*	water-air	Author
▽		1	5,790– 6,000	820–65,300*	water-air	Author
+		1	10,000–10,200	840–66,000*	water-air	Author

* × decreases as $(N_{Re})_G$ increases.

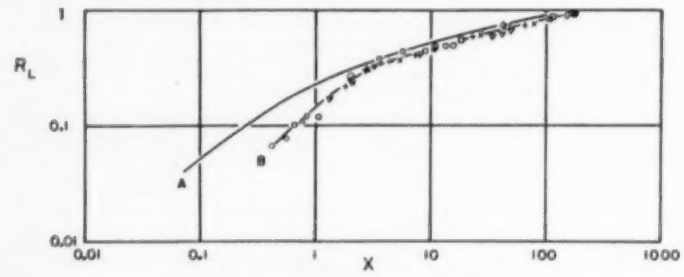

Fig. 12. Liquid holdup correlation.

(oil-air)

Curve A	Nominal Pipe diam., in.	$(N_{Re})_L$	$(N_{Re})_G$	System	Source
	Capillaries, ½ & 1	1.1–124,000	7–86,000	oil-air water-air	Lockhart & Martinelli
○	1	5– 7	711–75,000*	oil #-air	Author
△	1	14– 18	11,600–70,700*	oil #-air	Author
▽	1	54– 59	702–74,200*	oil #-air	Author
+	1	92– 99	694–74,600*	oil #-air	Author
×	1	122–128	709–74,200*	oil #-air	Author
□	1	253–286	765–21,800*	oil #-air	Author
◇	1	424–435	960– 5,020*	oil #-air	Author
●	1	485	955	oil #-air	Author

* × decreases as $(N_{Re})_G$ increases.
# S.A.E. 10 oil.

the type of equipment studied, however, because they include the effect of bends upon the flow in the passes.

Conclusions

1. Possible flow patterns obtainable in a cocurrent pipe-line liquid-gas contactor and representative photographs of many of these flow patterns for flow in straight horizontal pipes and in vertical upflow return bends were presented. The flow pattern regions for the flow of water-air and S.A.E.-10 oil-air mixtures in the straight sections of a 1-in. pipe-line contactor were correlated on a single chart as a function of the liquid and the gas velocities.

2. The pressure-drop data for the straight passes, including the effects of the return bends, indicated fairly good agreement with those predicted by the correlation of Lockhart and Martinelli. In general, the experimental values were higher than the predicted for annular flow and lower than the predicted for slug and wavy flows.

3. An ordinary threaded-type tee used as the inlet mixing section produced a pressure drop equal to an equivalent length of straight pipe of up to fifty-five diameters depending upon the liquid and gas flow rates.

4. The two-phase pressure drop expressed as equivalent length of straight pipe due to the 1-in. return bend of 7-in. radius with upward annular flow was of the same order of magnitude as that for single-phase flow.

5. For the flow of water-air mixtures, the water holdup data were up to 34% below those predicted by the correlation of Lockhart and Martinelli. Data for each constant water flow rate fell on separate curves of R_L vs. X. The liquid holdup data for the flow of S.A.E.-10 oil-air mixtures were from 14 to 54% below the predicted; yet the experimental results were within ±15% of a smooth curve on an R_L vs. X plot. The effect of liquid flow rate as noted for the flow of water-air mixture was not observed for the flow of oil-air mixture.

6. For annular flow limited data indicated that a considerable portion of the liquid can be entrained as a spray by the gas core depending upon the liquid and gas flow rates.

. The results reported in this paper can be used as a guide for the design of plant-scale cocurrent pipe-line liquid-gas contactors, even though scale-up information is still lacking.

Acknowledgment

The author wishes to acknowledge the preliminary planning on this research project by J. O. Maloney, presently at the University of Kansas. Thanks are due to L. W. Evans, W. F. Hart, and D. S. Webster for their assistance in the collection and reduction of the data, and to F. B. Cezus for his assistance in the photography.

Notation

$A = \frac{\pi D^2}{4}$ = cross-sectional area of pipe, ft.

D = inside diameter of pipe, ft.

f = Fanning-friction factor, dimensionless

F_1, F_2, F_3, F_4 = functions

g_c = conversion factor, 32.17 (lb./lb. force)(ft./sec.^{2})

L_e = equivalent length, ft.

ΔL = incremental length of pipe, ft.

$N_{Re} = \frac{VD\rho}{\mu}$ = Reynolds number, dimensionless

Δ_p = pressure drop for incremental length ΔL, lb.force/sq.ft., (except as noted)

P = power input (agitation), hp./1,000 gal.

q = volumetric rate of flow, cu.ft./sec.

R = holdup, expressed as a fraction of the total volume, dimensionless

$V = q/A$ = superficial velocity, ft./sec.

X = two-phase liquid-gas flow modulus (see Equations (5) and (8)), dimensionless

μ = viscosity, lb./(sec.)(ft.)

ρ = density, lb./cu.ft.

ϕ = function of X utilized in computation of two-phase liquid-gas flow pressure drop [see Equations (1), (2), and (8).], dimensionless

SUBSCRIPTS

b = bend

G = gas

L = liquid

t = tee

TP = two phase

tt = flow of both liquid and gas turbulent

tv = flow of liquid turbulent and flow of gas viscous

vt = flow of liquid viscous and flow of gas turbulent

vv = flow of both liquid and gas viscous

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Presented at A.I.Ch.E. San Francisco meeting.

the place of

sodium

in the new metals technology

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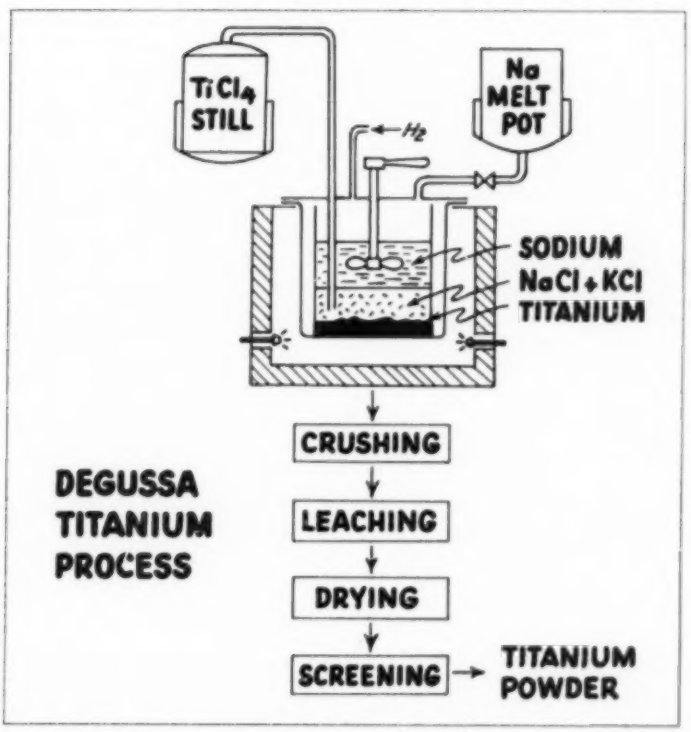

Fig. 1. Flow scheme of Degussa titanium process.

What is meant by a new metal, that is, new in commercial availability and importance?

Metallic sodium was discovered in 1807, was first made electrolytically on a commercial scale in 1891, but has only been available in quantity to all industries since 1952. Hence of itself, sodium really is a new metal.

Aggressive research and marketing programs are now finding many organic and inorganic uses for sodium. Organic uses in such fields as detergent and pharmaceutical manufacture, and hydrocarbon refining are of growing importance, and a broadening number of proposed inorganic applications are capitalizing on the fact that sodium is the lowest cost nonferrous metal.

This paper is concerned generally with the many ways in which sodium can contribute directly or indirectly to the advancement of the new metals technology, and, specifically with the uses of sodium in the production and finishing of the other new metals.

Sodium as a Reducing Agent

As a reducing agent for the production of metals from their salts was the earliest commercial use for sodium. Thus, Castner's early work, first on a modified Deville thermal reduction process and then on an electrolytic process, was inspired by the desire for cheaper aluminum, based on Oersted's disclosure in 1824 that sodium could reduce aluminum chloride into pure aluminum. The price of aluminum did fall from ten dollars per pound in 1886 to five dollars per pound in 1888 when Castner's iron carbide-caustic thermal reduction process was first operated at Oldbury, England, adjacent to a plant where aluminum was made by the use of sodium from aluminum chloride.

At this point in history the electrolytic process of Charles Martin Hall for aluminum came along and the sodium route to aluminum was discarded. Interest in the use of so active a metal as sodium has continued over the years, however, highlighted by Hunter's work on titanium manufacture in 1910. Increased incentive has recently been given to metallurgical applications of sodium by the demand for refractory metals in high-speed aircraft and missiles and in atomic-energy applications. It is with these metals, such as titanium, zirconium, thorium, vanadium, columbium, tantalum, molybdenum, and uranium that this paper is concerned.

Fig. 2. Operator adding sodium brick to hydride descaling bath.

Titanium

The first work on titanium preparation by sodium reduction of titanium tetrachloride was reported by Nilson and Petterson in 1887 (*5*). Then in 1910, Hunter's experiments in a steel bomb marked something of a milestone as titanium tetrachloride reduction by sodium is still referred to today as the Hunter process. Hunter charged the steel pressure vessel with titanium tetrachloride and sodium, heated it to 600-700° C. to initiate the reaction, and obtained a 70% yield of fused metallic lumps which analyzed 99.7-99.8% titanium (*3*).

In 1914, Lely and Hamburger described the preparation of titanium and of thorium, uranium, and zirconium, as well, by sodium reduction (*4*).

A desire to eliminate high-temperature operations and the use of pressure vessels led to Billy's work on the reduction of titanium tetrachloride with sodium hydride in 1921 (*1*). The tetrachloride vapor was passed over heated trays containing sodium hydride. The titanium product of this reaction contained hydrogen, however, which had to be removed by heating to 800° C. in a vacuum.

The first attempt at commercialization of the sodium reduction route to titanium was that of the German firm of Degussa, in the early 1940's (*2, 6*). The process flow sheet for the Degussa operation is shown in Figure 1. As indicated there, the reaction vessel had a removable iron liner which was charged with a mixture of sodium chloride, potassium chloride, and sodium metal. Upon heating to 700-900° C. a sodium layer was formed which surmounted a layer of molten salt. The motor-driven agitator stirred only the sodium layer and caused no mixing of the salt and sodium layers. Then the titanium tetrachloride vapor was introduced beneath the salt layer to prevent blocking the end of the inlet pipe with reaction products. The reduction actually took place at the salt-sodium interface. A single autoclave charge in the Degussa process consisted of

15 kg. NaCl
15 kg. KCl
46 kg. Na
85 kg. $TiCl_4$

A 98% titanium product was obtained, the main impurities being oxygen and iron from the reaction vessel.

The Titanium Alloy Manufacturing Co. in this country has reported work on the Hunter bomb technique for titanium manufacture and other companies are actively interested in the sodium route.

To sum up the reduction processes for titanium—sodium should definitely be considered as an alternate for part or all of the presently used agent, magnesium, in the reduction of titanium tetrachloride. Sodium is an effective reducing agent and can be produced at low cost in a state of high purity and probably can be employed instead of magnesium in an improved version of the Kroll process (*8*). Table 1 gives a cost comparison of sodium, magnesium, calcium, and sodium hydride as agents for the reduction of titanium tetrachloride.

A second such technique is based on the use of sodium amalgam. It has been claimed that amalgam makes the reduc-

Table 1.—Cost of Comparison of Agents for $TiCl_4$ Reduction

Reducing Agent	lb. Req'd lb. Ti Produced	Cost of Reducing Agent, $/lb. Agent	Cost of Reducing Agent, $/lb. Ti
Na	1.92	$0.16	$0.307
Mg	1.00	0.245	0.245
Ca	1.67	2.00	3.34
NaH	1.00	1.80	1.80

ing metal available in easily handled form, makes the product easy to shield from oxygen and nitrogen, and simplifies separation of the metal product. In the case of sodium, however, amalgams containing greater than ½ of 1% sodium are not fluid at room temperature and not as easily handled. Therefore, a relatively large volume of mercury would have to be handled in order to transport a relatively small amount of sodium in a plant.

So much for the possibilities of sodium in the production of titanium. There are a number of possibilities in the metallurgy of the other new metals.

Zirconium, for example, can be treated in much the same way as titanium. In the case of zirconium, however, potassium zirconium fluoride may be a desirable starting material for sodium reduction instead of zirconium tetrachloride.

The commercial method for the production of metallic potassium involves reaction of a mixture of sodium metal and potassium chloride.

Some of the other metals which have been prepared by sodium reduction at one time or another, even though commercial processes have not been developed, are summarized in Table 2, along with a listing of the salts of these metals which are known to be susceptible to sodium reduction.

The potential for sodium as a reducing agent in the production of the new metals leads to a consideration of its uses in the finishing of the new metals.

Sodium As Finishing Agent

Just as the sudden advent of titanium into the industrial metals field has created many metallurgical problems, so has it created problems in finishing. Conventional pickling operations are not very successful in the removal of scale from hot-rolled titanium.

However, titanium sheets, ranging in thickness from 1 to 0.015 in., have been successfully descaled with sodium hydride (*7*) by a process already tried and proved for steel and stainless steel.

In some early work on thin titanium sheets difficulty was experienced with the titanium burning in air upon removal from the bath. The difficulty centered at the base of the rack where any drag-out accumulated between sheets closely spaced in the rack. Sufficient heat was generated to burn large holes completely through the thin sheets, even though the rack was transferred to the water quench bath as rapidly as possible. Operation of the bath at 680-700° F. with care never to go above 700° F. has however usually eliminated this problem.

Descaling of titanium sheets commonly takes 15 min. of immersion in the sodium hydride bath. The work is then transferred to a water-quench tank and then to a pair of acid-wash tanks in one typical mill's operation. An 8% sulfuric acid bath at 100° F. is first used for one minute. Then, a bath containing 6% nitric acid and 1% hydrofluoric acid at room temperature is used for ½ min. A final water spray completes the over-all operation.

In addition to its application to the descaling of titanium, the hydride bath is the preferred medium for the descaling of hafnium.

The metal scales which have been successfully reduced with sodium hydride are summarized in Table 3.

Miscellaneous Applications

Sodium has a place not only in metal reduction and in metal descaling, but also in miscellaneous metallurgical application, such as in high-speed aircraft and missiles and in atomic energy applications as mentioned previously. Thus sodium has long and successfully been used in the modification of aluminum alloys—to obtain better casting definition, and to achieve improved physical properties through grain refinement.

Some work has been done with sodium in deoxidizing and desulfurizing metals and alloys. Also, sodium may be used as a wetting agent for other liquid metals in operations such as hot dipping.

Sodium forms alloys with a large number of other metals. These alloys can serve as heat-transfer media, as controlled chemical reactants, as drying agents for gases and liquids, as means of introducing metallic additions to other metals, and in many other ways.

Table 2.—Some Metal Salts Reduced by Sodium

Metal	Chloride	Oxide	Complex Salts
Ti	$TiCl_4$	.....	.....
Zr	$ZrCl_4$	.....	K_2ZrF_6
Th	$ThCl_4$	.....	.....
U	UCl_4	.....	.....
V	VCl_4	.....	.....
Ta	.....	.....	K_2TaF_7
In	$InCl_3$	In_2O_3	.....
Th	$ThCl_4$	.....	.....
Fe	$FeCl_3$	Fe_2O_3	.....
Zn	$ZnCl_2$	ZnO	.....
Cu	$CuCl_2$	CuO	.....
Ni	$NiCl_2$	NiO	.....
Pt	.....	.....	H_2PtCl_6
Si	$SiCl_4$	.....	.....
B	BCl_3	B_2O_3	.....
Al	$AlCl_3$	.....	.....
Cr	$CrCl_3$	Cr_2O_3	.....

Table 3.—Metal Scales Reduced With Sodium Hydride

Metal	M_2O_3	M_3O_4	MO	M_2O	MO_2
Fe	Yes	Yes	....	....	....
Cu	....	....	Yes	Yes	....
Cr	....	Yes*	....	....	....
Ni	Yes	Yes	Yes	....	....
Ti	....	....	Yes	....	Yes
Hf	....	....	....	....	Yes
Ag	....	....	....	Yes	....

* To CrO_3.

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simultaneous heat and mass transfer in a diffusion-controlled chemical reaction

PART I. Studies in a Tubular Reactor

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The rates of heat and mass transfer which occur simultaneously in a solid-gas reaction have been measured for the first time in a diffusion-controlled chemical reaction having sufficiently simple kinetics that the results may be quantitatively compared with the theory and the experimental correlations developed from nonreacting systems. The results are analyzed with equations which were developed to predict the relationship between the length of a tubular reactor and the degree of heterogeneous reaction of a gas flowing through it. The reaction studied was the heterogeneous decomposition of vapor mixtures of hydrogen peroxide and water.

The observed mass transfer rates are correlated with an average deviation of 9.5% by the equation: $j_D = 0.021(N_{Re,f})^{-0.2}$. The heat transfer results are correlated with an average deviation of 14.8% by $j_H = 0.023(N_{Re,f})^{-0.2}$. The j_H/j_D ratio equals 1.09, with an average deviation of 13.7%. The maximum temperature which a surface may reach in a diffusion-controlled chemical reaction is also considered.

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This two-part paper is a quantitative study of the rates of heat and mass transfer occurring simultaneously in an exothermic, transport-rate controlled gas-solid reaction. The correlations obtained here are compared with mass transfer and heat transfer data in the literature, which have heretofore been obtained separately from one another. The temperature which a surface may attain under simultaneous heat and mass transfer is also examined quantitatively. The chemical reaction chosen for this study was the decomposition of vapor phase mixtures of hydrogen peroxide and water on an active, nonporous catalyst surface of metal.

Two different geometrical systems were investigated. Part 1 is concerned with the flow of hydrogen peroxide vapor through a cylindrical tube; Part 2, with studies in a bed packed with spheres of the same catalytic metal.

The present study is believed to be the first in which the rates of simultaneous mass and heat transfer have each been determined in a diffusion-controlled chemical reaction having sufficiently simple kinetics that the results can be quantitatively compared with both the theory and the experimental correlations developed from nonreacting systems.

The most important example of a diffusion-controlled reaction is the high temperature combustion of carbon. Hottel and coworkers (*4, 17, 23, 25*) have reported several studies on this system, but, because of uncertainties of the gas-phase kinetics and other difficulties, it has not been possible as yet to predict quantitatively high temperature combustion rates from correlations of heat or mass transport data.

Diffusion-controlled reacting systems are further complicated by the presence of a large temperature gradient between solid and bulk gas and of bulk flow between the surface and the gas stream. Such temperature gradients have been observed in various systems in addition to the combustion of carbon. For example, Apel'baum and Temkin (*1*) found in the catalytic oxidation of ammonia that the platinum surface was at a higher temperature than the gas passing through the gauze. Hougen and Watson (*9*) and Yang and Hougen (*30*) have used heat and mass transfer data independently obtained and simul-

taneous heat and mass transfer rates determined from evaporation of liquids, to estimate the extent to which an observed chemical reaction is diffusion-controlled and the corresponding temperature difference between solid surface and gas stream. No experimental verification has been reported of such predicted temperature differences.

Detailed reference will not be made here to the many previous investigations of heat and mass transfer inside tubes and the analogies between the two. The present status of the theory and experimental data relating these transfer processes have been recently outlined by Sherwood (*20*) and Sherwood and Pigford (*21*). It may be noted here that the Reynolds analogy and those developed by von Karman (*10*), Martinelli (*16*), and Chilton and Colburn (*3*) give very close agreement at Prandtl and Schmidt numbers near 1.0. In the present investigation the Prandtl number is 1.0 and the Schmidt number varies from 0.7 to 0.9; therefore the data obtained here will have essentially the same agreement with all these relationships and cannot be used to differentiate among them.

The vapor-phase decomposition of hydrogen peroxide on an active, nonporous catalyst surface, which was chosen for this study, exhibits the following desirable characteristics: 1) highly irreversible; 2) having no side-reactions; 3) having all reaction at the surface (i.e., completely heterogeneous); 4) simple in chemical-reaction mechanism, and 5) rapid in surface reaction relative to the mass transport rate. It has a major, and most fortunate, difference from the high-temperature oxidation of carbon in that the only two products formed appear in a fixed and known ratio to one another, namely, water and oxygen, produced according to the equation,

$$2H_2O_2(g) \rightarrow 2H_2O(g) + O_2. \qquad (1)$$

No other species appear to be present except possibly very small concentrations of the free radicals OH and HO_2 formed and consumed (*18*) during the reaction. This allows an exact diffusion-controlled reaction mechanism to be formulated and, consequently, permits a method to be developed for predicting the rate of transport in such a gas-solid system.

Development of Mass Transfer Equations

The physical picture presented in the development of a diffusion equation for this system is quite complex, involving the nonequimolecular counterdiffusion of hydrogen peroxide, water and oxygen under both a concentration and temperature gradient between the catalyst surface and the bulk stream. The total resistance to the mass transport of hydrogen peroxide is the combination of the resistance to bulk and molecular transfer through the eddy, buffer, and laminar regions of the gas stream, complicated by the presence of a bulk flow of gas from the wall to the stream caused by an increase in the number of moles during the reaction. Although it has been demonstrated (*22*) that eddy diffusion plays an important role, it is customary to visualize the transport as occurring through a single laminar film, the thickness of such an "effective" or "fictitious" film being so chosen as to incorporate all resistance to diffusion. This technique, although basically not a true description of the actual transfer mechanism, does allow the prediction of transport rates with sufficient accuracy for most engineering applications.

The basic differential equation describing mass transport through such a film is

$$y_A y_B (u_A - u_B) = -D_{AB} \frac{dy_A}{dx} - \frac{D_T}{T} \cdot \frac{dT}{dx} \qquad (2)$$

If thermal diffusion is ignored for the moment, integration of Equation (*2*) over the diffusion path from stream to tube surface for steady state conditions gives

$$N_A x_D = (D_{Am} P \phi_A / RT) \ln (\phi_A - y_{Aw})/(\phi_A - y_{Ab}).^* \qquad (13)$$

Although slightly different in form, this equation is identical to the equation for nonequimolecular counterdiffusion proposed by Hougen and Watson (*9*) and for the present system gives values within 1% of the results obtained by use of the more rigorous solution developed by Gilliland (*6*) in the form of two simultaneous equations. The difference between the results of the various equations becomes significant only when the ratio of molal rates of diffusion of two of the components becomes greater than approximately ten to one. This is not likely in most chemical reactions where the molal ratio of reactants to products (or the reciprocal) is seldom greater than about three to one; for example, in hydrogen peroxide decomposition the ratio is two to three.

For an integral reactor, such as is employed in the present work, Equation (13) must be integrated along the catalyst tube. The following assumptions were made: 1) axial heat transfer is negligible, 2) axial diffusion is negligible, 3) entrance effects may be neglected, 4) the partial pressure of the hydrogen peroxide vapor at the catalyst surface is zero (that is, reaction is completely diffusion-controlled), 5) no homogeneous reaction occurs, 6) a constant average value of the effective film thickness may be employed along the tube.

Assumptions 1, 2, and 3 may be readily justified by the design of the apparatus. Assumptions 4 and 5 are borne out by the experimentally-found effects of surface temperature, concentration, and flow rate on the observed rate of decomposition. No quantitative basis is available by which deviations from assumption 6 can be accounted for in the mathematical development. The coefficient D_{Am} can be obtained for two-component systems from the empirical equation of Gilliland (*6*). As a check, this equation was found to be in excellent agreement with the experimental data of McMurtrie and Keyes (*15*) on the diffusion of hydrogen peroxide vapor in air.

For the three-component system here, D_{Am} can be obtained by the weighted average of the binary diffusivities recommended by Hougen and Watson (*9*), the harmonic mean of Wilke (*27*), or Seader's general equation (*19*) (obtained by simplification of Wilke's method for the case of a gaseous reaction catalyzed by a solid catalyst). In this particular system virtually identical values for D_{Am} are obtained by the various methods:

$$D_{Am} = 1.73 \times 10^{-4} T^{3/2} \text{ft.}^2/\text{hr.} \quad (T = {}^\circ\text{K.}). \qquad (50)$$

The integration requires a method of representing the diffusivity and temperature of the gas within the film as a function of length. At any point in the tube the average diffusivity across the film was assumed equal to that at a film temperature calculated as the arithmetic mean of the bulk stream and wall temperatures. A constant average film temperature over the length of the tube may then be calculated as the arithmetic average of the entrance and exit film temperatures.

The integrated equation is then:

$$\frac{y_{A2} - y_{A1}}{(y_{A2} - \phi_A)(y_{A1} - \phi_A)} + \frac{2}{\phi_A} \ln \frac{y_{A2}(y_{A1} - \phi_A)}{y_{A1}(y_{A2} - \phi_A)} = \frac{D_{Am} P}{RT_a x_D u_a} \cdot \frac{2h'}{(h' - \phi_A)} \cdot \pi DL \cdot ^* \qquad (27)$$

Actually, however, the bulk stream temperature under adiabatic conditions is a linear function of the fraction of the entering hydrogen peroxide decomposed

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* For detailed mathematical derivation of the equations presented and Tables 1 and 2 order document 4317 from A.D.I. Auxiliary Publications Photoduplication Service, Library of Congress, Washington 25, D. C., remitting $1.75 for microfilm or $2.50 for photoprints.

Equation numbers correspond to those given in the more detailed presentation.

(28), and a more accurate equation should allow for this. Thus,

$$T_s = c'f + d'. \tag{28}$$

If this is combined with the average wall temperature, the relationship for the film temperature is

$$T_f = cf + d. \tag{29}$$

By integration and conversion into terms of f one may obtain an alternate equation,* which in principle should be preferred:

$$2n_a(\phi_A - h')\left[\frac{2}{\sqrt{c+d}}\right.$$

$$\left.\tanh^{-1}\sqrt{1-\frac{c(1-f)}{c+d}}\right]_{f_1}^{f_2}$$

$$+ h'\left[\frac{2n_a\sqrt{c+d}}{c}\sqrt{1-\frac{c(1-f)}{c+d}}\right]_{f_1}^{f_2}$$

$$= \frac{2aP'\phi_A h'}{Rx_D}\pi D l. \tag{35}$$

Development of Heat Transfer Equations

Under the assumptions specified, all the heat liberated at the catalyst surface under adiabatic steady-state operation must be transferred back to the stream. Therefore, the magnitude of the temperature difference between surface and stream is governed by the relative rates of mass diffusion to the surface and heat transfer from the surface. Heat transfer from the wall to the stream by radiation here is negligible due to the low emissivity of the catalyst and the very low beam length in the system. By consideration of the flow of heat and mass in and out of a gas layer of thickness dx, an equation may be developed which allows for conduction and the sensible heat carried by the diffusing materials:

$$k\frac{d^2T}{dx^2}dx + (N_P C_{p_P} - N_R C_{p_R})\frac{dT}{dx}dx = 0. \tag{36}$$

Solving for T at a distance x within the film, one obtains

$$T = \beta_1 + \beta_2 e^{-\left(\frac{N_P C_{p_P} - N_R C_{p_R}}{k}\right)x}. \tag{37}$$

The constants of Equation (37) can be determined from the boundary conditions $x = 0$, $T = T_S$ and $x = x_W$, $T = T_W$:

$$T = T_S + \left(\frac{T_W - T_S}{e^{-Kx_w} - 1}\right)(e^{-Kx} - 1) \tag{38}$$

where

$$K = (N_P C_{p_P} - N_R C_{p_R})/k. \tag{39}$$

From the heat capacities of steam (11), oxygen (2), and hydrogen peroxide vapor (2), the value of the exponent (Kx_w) is found to vary from −0.02 to +0.01 over the range of operating temperatures and flow rates. It becomes zero at a film temperature of approximately 600° F. With the value zero, Equation (38) becomes in the limit,

$$T = T_S + \frac{x}{x_w}(T_W - T_S). \tag{40}$$

which states that the temperature is a linear function of the distance through the film. Therefore heat transfer by conduction alone need be considered. Calculations using the range of values of the exponent show that the gradient still remains essentially linear and therefore that heat transfer by the motion of the diffusing particles is negligible for the entire range of operating variables.

In a detailed analysis of the effect of mass transfer on the heat transfer coefficient, Squyres (24) determined that the ratio of the actual coefficient of heat transfer to that without mass transfer was dependent on a parameter which is equal to Kx_W. For the range of values of Kx_w in the present work, this ratio of heat transfer coefficients ranged from 0.99+ to 1.01−, agreeing with the conclusion drawn above that the mass transfer in this study is not of sufficient magnitude to affect the heat transfer coefficient.

Therefore a heat balance across the film reduces to

$$N_A\Delta H = k\frac{dT}{dx} = h\Delta t \tag{41}$$

where N_A is the rate of diffusion of hydrogen peroxide to the surface per unit area and ΔH is the heat liberated by the reaction at the surface temperature. The equation may be easily modified to allow for heat losses from the surface, where they occur.

Effect of Thermal Diffusion

Furry and Jones (5) introduce the relationship

$$D_T = D_{AB}y_A y_B\alpha \tag{42}$$

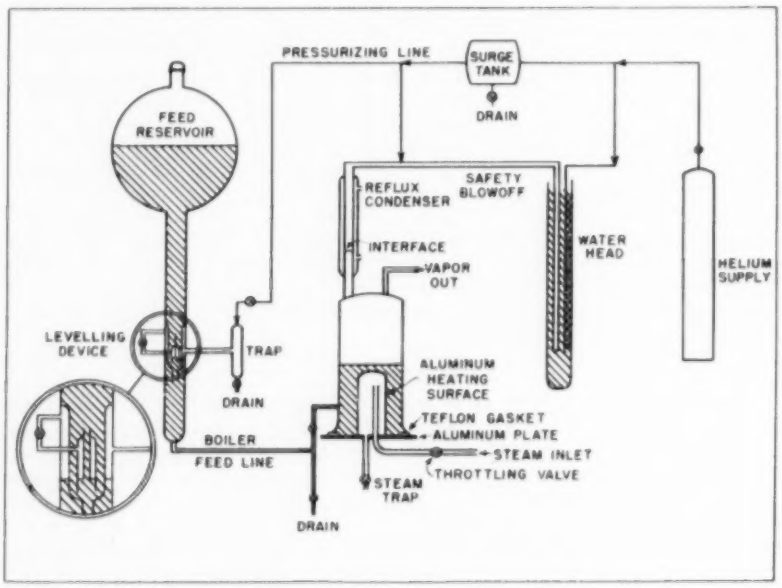

Fig. 1. Hydrogen peroxide vaporization system.

where the coefficient α is independent of pressure but is dependent on temperature and probably on the concentrations. As with Equation (13) there may be developed from Equation (2) the rate of mass transfer under simultaneous thermal and concentration gradients:

$$N_A dx = \frac{\phi_A D_{Am} PTk dy_A}{\phi_A D_{Am} P\alpha(\Delta H)y_A(1-y_A) + RT^2 k(\phi_A - y_A)}. \tag{44}$$

Integration across the film results in:

$$N_A x_D = l'\left[\frac{-2}{\sqrt{4n'\phi_A m' + (n'-m')^2}}\right.$$

$$\left.\tanh^{-1}\frac{2m'y_A + (n'-m')}{\sqrt{4n'\phi_A m' + (n'-m')^2}}\right]_{y_{AS}}^{y_{AW}}. \tag{49}$$

Further integration of Equation (49) does not seem possible except by numerical approximation methods. However, the effect of thermal diffusion in the system can be obtained by comparing Equation (49) with Equation (13). Unfortunately no values of α are available or can be estimated with any ac-

curacy for the present system, which is highly polar. Nevertheless, calculations using values of a ranging from 0.0 to 0.3, suggested from various nonpolar systems (*26, 29*), show a maximum decrease in the calculated effective film thickness of 1.5% at the highest average temperature gradient found in the present work (300° F.). In spite of the uncertainty concerning the actual value of a here, it appears that the thermal diffusion effect can be considered slight. Indeed, thermal diffusion has always been considered unimportant in dynamic mass transfer situations; however, this calculation supplies a quantitative basis for such an assertion.

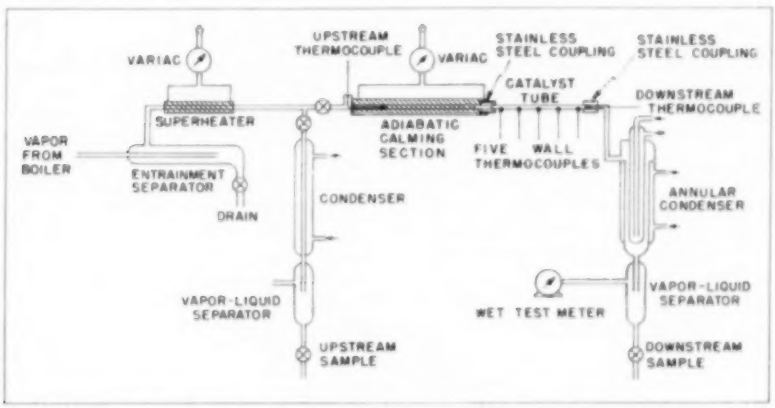

Fig. 2. Catalyst tube decomposition apparatus (shown without insulation).

Experiment

A hydrogen peroxide solution of suitable composition was introduced continuously into a vaporization system, shown in Figure 1, which was especially designed to produce a vapor stream at a constant rate and of constant composition. To this end a special levelling device, described by Holmes (8), was used, the device being connected to the boiler through a line filled with a noncondensable gas. Helium was chosen for this purpose because it is inert and lighter than the vapors formed. The boiler was operated at pressures of up to 32 in. of water to give the flow rates desired.

The vapor passed through an entrainment separator and a superheater (Figure 2), which ensured complete vaporization. Part of the vapor stream was then withdrawn, condensed, and subsequently analyzed while the remainder flowed through a 0.250-in. I.D. precision-ground Pyrex calming section into a 0.250-in. I.D. catalyst tube. The vapor temperature was measured at the entrance to the calming section and the calming section was made adiabatic, so that the temperature at the inlet of the catalyst tube could be determined accurately without disturbing its flow characteristics. Adiabaticity was obtained by winding a heating coil on the insulation around the approach section and adjusting the heat input through the coil so that no temperature difference occurred between the glass tube and the insulation. Thus zero heat flow was insured.

The glass calming section and the catalyst tube were connected by a stainless steel coupling and Teflon gasket, which gave a smooth connection between the glass and catalyst tubes. No discontinuity could be felt when a sharp-pointed probe was passed perpendicular to the surface across the joint. Two catalyst tubes were used in different runs, one 18 in. in length, the other 24 in. The catalyst was a metal of high thermal conductivity; the inside tube surface was smooth and was not affected chemically by the decomposition reaction.

After leaving the catalyst tube, the vapor stream flowed through a condenser, the condensate was removed in the separator, and the oxygen rate was determined by a wet-test meter. After each run the liquid samples were immediately analyzed for peroxide content by titration with standardized potassium permanganate solution.

The adiabatic calming section and catalyst tube were supported in blocks of foam-glass insulation and the remainder of the apparatus from the boiler to the condensers was insulated with Pyrex glass wool and wrapped with aluminum foil. Except for the catalyst tube and aluminum heating finger and plate, construction was entirely of Pyrex glass, ground glass ball joints being used to connect units.

Copper-constantan thermocouples were silver-soldered to the catalyst tube wall at five positions: 1, 3, 10, 16, and 22 in. from the upstream end in the 24-in. tube and 1, 3, 9, 15, and 17 in. from the upstream end in the 18-in. tube. Two thermocouple probes, inserted in glass wells, measured stream temperatures at the entrance to the adiabatic section and at the exit of the catalyst tube. In addition, six other thermocouples were placed in the insulation of the adiabatic calming section in order to insure its correct operation.

The experimental conditions studied were as follows: inlet hydrogen peroxide concentration, 3 to 32 wt. %; catalyst surface temperature, 400° to 1,000° F.; Reynolds number, 3,200 to 10,000. The surface temperatures attained were largely dependent on the other variables but could be varied somewhat by the degree of superheat.

Results

The data obtained for each run included volumes and peroxide concentrations of upstream and downstream liquid samples, the volume of oxygen leaving the downstream condenser, and temperatures of the catalyst tube and of the inlet and exit gas streams. From these experimental data could be calculated the exact concentration of the gases entering and leaving the tube, y_1 and y_2 respectively, and the amount of decomposition resulting from passage through the tube, called w. These values were then substituted in the theoretically derived Equations (*27*) and (*35*) in order to obtain values of x_D, the effective film thickness for mass transfer. The results of the two equations were found to agree within one per cent, although the value given by Equation (*35*) would be preferred since it considered a varying film temperature along the tube. Use of Equation (51) then allowed conversion of the effective film thickness to the coefficient of mass transfer, k_G, which could be correlated on the basis of j-factor expressions:

$$k_G = \frac{D_{Aw}P}{RTx_{Dp'BM}} \qquad (51)$$

In the past most investigators have treated integral reactors by the use of a point-rate expression equivalent to Equation (13) evaluated at some average set of conditions along the reactor. To test the adequacy of this method, average conditions within the tube were taken to be represented by the point in the catalyst tube at which the log mean partial pressure driving force occurred. The values of x_D calculated at this point by the use of Equation (13) agreed within two per cent with the values determined from the more elaborate integrated Equations (*27*) and (*35*). Examination of the final results showed that the change in physical properties over the range of temperatures studied was such that various choices of average conditions affected the correlation negligibly. (The average deviation changed less than 1%.)

Values of the heat transfer coefficient were calculated by means of Equation (41), the heat transfer term being corrected for the amount of heat loss from the catalyst tube section to the surroundings, which ranged from 2 to 40%, and averaged about 15 to 20%. It was neither necessary nor practicable to make the system completely adiabatic.

The maximum error in the final calculated values of j_D due to inaccuracies

in physical measurements was believed to be less than 2%. Although the thermocouple readings were accurate to within 3° F., there existed the possibility of errors as large as 15% in j_H in some of the runs with very small temperature differences. However, in most of the runs the maximum error was on the order of 5%.

Table 1 * presents a summary of the experimental data, including inlet and exit gas stream concentrations and temperatures, flow rates, and temperatures measured along the catalyst tube wall. Table 2 * presents the calculated results, including the calculated mass and heat transfer factors.

Figure 3, which depicts a typical temperature profile of the tube and gas stream, is discussed below. Figures 4 and 5 are plots of the mass and heat transfer factors, j_D and j_H, vs. the film Reynolds number $N_{Re,f}$. Also included in these figures is the line representing the Chilton-Colburn correlation (*3*).

Discussion of Results

PROOF THAT THE REACTION IS DIFFUSION-CONTROLLED

The conclusion that the measured reaction rate is controlled by the rate of diffusion to the surface is proved by three facts. (1) The values of j_D found here agree closely with those determined elsewhere in nonreacting systems. (2) The values of j_D here give a slope of −0.2 on a plot of j-factor versus Reynolds number. A slope of this value has been found in other work where the total driving force is used in overcoming resistance to mass transfer. In contrast, if a system which is actually surface rate controlled is considered, experimentally determined j-factors calculated on the assumption of a diffusion-controlled system would give a −1.0 slope when plotted against the Reynolds number. Systems in which both processes are important would exhibit slopes between −0.2 and −1.0 on such a plot. (The average deviation of 9.5% in the tube data combined with the relatively short range of Reynolds numbers studied might cast some doubt as to whether the slope in Figure 4 is truly −0.2; however the data obtained in a packed bed, described in Part 2, exhibit a much smaller spread and also lead to the same conclusion.) (3) The data plotted in Figure 4 were obtained over a wide range of wall temperatures, 400° to 1,000° F. If the surface reaction rate had constituted a significant part of the total resistance, the results would have varied greatly with temperature. No such trend with temperature was noted.

MASS TRANSFER CORRELATION

The mass transfer data plotted on Figure 4 have an average deviaiton of 9.5% from the best line which may be expressed by the equation

$$j_D = \frac{k_G M_M p_{BM}}{G} (N_{Re,f})^{\%}$$

$$= 0.021\,(N_{Re,f})^{-0.2}. \qquad (57)$$

Because of the spread of the data and the small effect of even large temperature differences on the physical properties of the gas stream, the data can be correlated almost as well by using $N_{Re,s}$, the stream Reynolds number.

The data indicate a straight line with Reynolds numbers as low as 3,200, a value which is well within the transitional range. The absence of the dip which Chilton and Colburn (*3*) indicate in this region could be ascribed to turbulence generated by the simultaneous effect of heat transfer. However, examination of the isothermal mass transfer data of Gilliland and Sherwood (*7*) and the heat transfer data of many investigators shows the same straight line when dealing with gas streams. It is probable, therefore, that the dips are more evident with viscous fluids and the straight-line correlation to 3,200 is normal.

The correlation used here is parallel to, but 9.5% below, that recommended by Chilton and Colburn (*3*).

$$j_D = 0.023(N_{Re,f})^{-0.2}. \qquad (54)$$

Their coefficient, obtained by equating j_D to the best value for j_H, is found to agree within 25% with mass transfer data in systems of solution and evaporation. The coefficient of 0.021 proposed here is within the range of 0.020-0.027 found by other investigators. The lower value of the coefficient obtained here might be attributed to (1) the temperature gradient and simultaneous heat transfer, (2) the effect of counterdiffusion and bulk flow through the film, (3) thermal diffusion, or (4) end effects. Each of these possibilities was examined, but no one of them appears to be of particular significance here.

The present data average 27% below the correlation of Gilliland and Sherwood (*7*) for certain wetted-wall data. The agreement of the data with the von Karman and Martinelli equations mentioned is the same as the agreement with the Chilton-Colburn correlation.

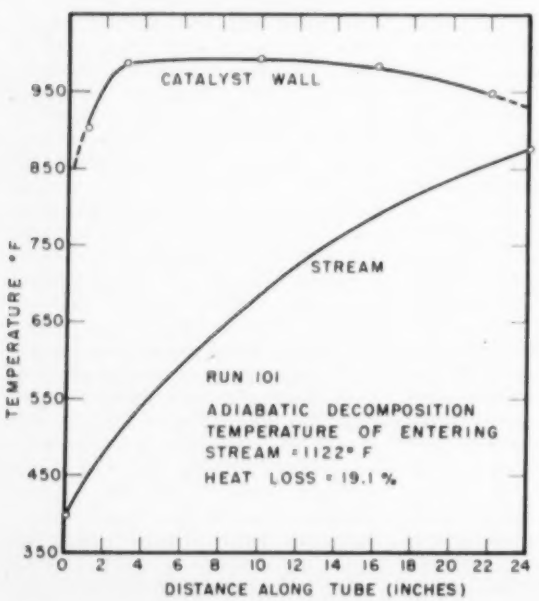

Fig. 3. Typical temperature distribution in catalyst tube.

HEAT TRANSFER CORRELATION

The actual amount of heat transferred to the vapor stream as it flowed through the tube was calculated from the measured inlet and exit temperatures and the known heat capacities of the species present. The increase in kinetic energy was found to be negligible. To obtain the percentage heat loss, the actual sensible enthalpy gain was compared with the increase in enthalpy that would have resulted from the known amount of decomposition if the system had been adiabatic. Over-all coefficients of heat transfer were then calculated by use of the logarithmic mean of the difference between the average wall temperature and that of the entrance and the exit gas. This method involves inaccuracies because of the assumption of constant wall temperature and because of the large error in measuring the small temperature differences between the tube wall

* See footnote on page 461.

and the gas leaving the tube. Point heat transfer coefficients were also calculated, therefore, for that position in the tube at which the partial pressure difference between stream and wall is equal to the log mean of the partial pressure differences at the two ends of the tube. Equations (13), (35), and (28) were used.

The results obtained by both methods are consistent with the Chilton-Colburn correlation and also with the heat transfer equation given by McAdams (14):

$$j_H = \frac{h}{C_p G}(N_{Pr,f})^{2/3} = 0.023(N_{Re,f})^{-0.2} \quad (52)$$

The point value data, plotted in Figure 5, have an average deviation of 14.8%; the log mean values, considered less accurate and less reliable, give an average deviation of 22.4%. The degree of agreement is not so good as the mass transfer data, because of the inaccuracies in measuring temperature differences and heat losses and also possibly because the data lie primarily in the transitional region, where large deviations are usually encountered.

The present work gives a ratio of 1.09 with an average deviation of 13.7%, a value which is in excellent agreement with the assumption of equality.

CATALYST SURFACE TEMPERATURE

From Equation (41) and the definition of the mass transfer coefficient k_c, one obtains

$$k_c c \Delta H = h \Delta T \quad (58)$$

The concentration of the stream, c, represents the entire gradient since the wall concentration is zero. Substituting into Equation (58) with the expression for j_H and j_D as given by Equations (52) and (54), and remembering that $G = \rho \cdot U$, one obtains the relationship:

$$\Delta t = (j_D/j_H)(P/P_{BM})(N_{Pr}/N_{Sc})^{2/3}(c \cdot \Delta H)/(C\rho \cdot \rho). \quad (59)$$

If the concentration of the diffusing component is small, (P/P_{BM}) is nearly unity. The Prandtl and Schmidt numbers are nearly equal in this and many other systems. Under these circumstances and assuming $j_H = j_D$, Equation (59) reduces to

$$\Delta T = c\Delta H/C\rho \cdot \rho \quad (60)$$

The numerator, $c\Delta H$, is the heat released by the reaction of a given volume of the gas, the denominator is the volumetric specific heat of that gas, and so the quotient is the temperature increase on complete adiabatic reaction. Therefore, under such conditions the temperature reached by the wall is equal to the adiabatic reaction temperature for complete reaction of the gas passing that point. Since this calculated temperature is independent of the extent to which adiabatic reaction has previously occurred, the entire wall surface would be at the adiabatic reaction temperature for complete reaction of the entering gas stream.

The surface temperature for any real system can be either above or below the adiabatic reaction temperature depending on the j_H/j_D ratio, the concentration of the reacting gas or gases, and the values of the Prandtl and Schmidt numbers. Any variation from adiabaticity will, of course, also affect the surface temperature. If heat is lost from a tube wall, as is the case here, the decomposition temperature of the gas will steadily decline as it passes through the tube, and the wall temperature would be expected to drop steadily.

The exact shape of the temperature profile of Figure 4 can now be interpreted. Here the j_H/j_D ratio is approximately unity and the Schmidt and Prandtl numbers are almost the same. Since a 19.1% heat loss was experienced in the run illustrated in Figure 4, the maximum wall temperature reached is slightly below the adiabatic decomposition temperature and falls off steadily towards the exit, as would be expected from the discussion presented above. The sharp temperature dip at the entrance was caused by the coupling between the glass calming section and the catalyst tube which acted as a high thermal conductivity path from the front end of the tube to the cooler adiabatic calming section, resulting in relatively large heat losses. The coupling at the exit of the tube was insulated from any cool section and therefore did not cause such large heat losses at that point. The initial dip is probably *not* due to the process of establishing temperature and concentration gradients at

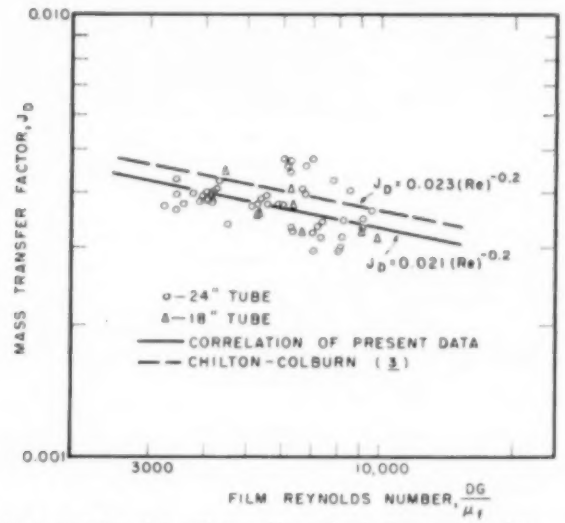

Fig. 4. Variation of J_D with Reynolds number in flow through tubes.

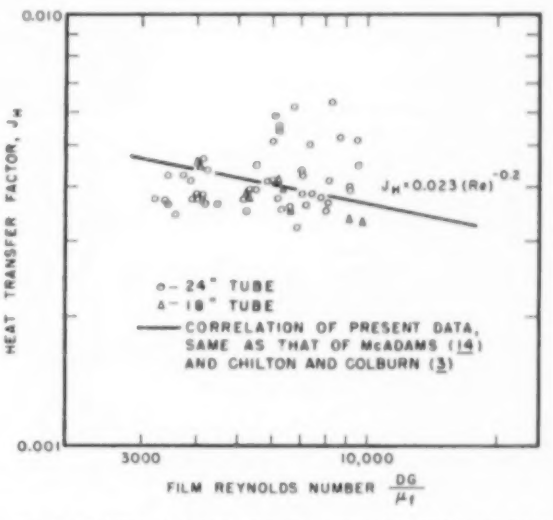

Fig. 5. Variation of J_H with Reynolds number in flow through tubes.

RATIO OF j_H to j_D

A principal advantage in the use of j_H and j_D has been the assumption of their equality in similar physical systems and therefore the possibility of using heat transfer data to predict mass transfer rates and vice versa. This assumption follows from the development of the Reynolds analogy as well as from dimensional analysis (12) and is supported by data on evaporation of liquids which show values of the j_H/j_D ratio from 0.8 to 1.5.

the entrance of the tube since both heat and mass transfer rates would be increased simultaneously and therefore maintain the same wall temperature as occurs downstream. The length-to-diameter ratios used here make the entrance effects negligible on the over-all results.

It may be concluded that the wall temperatures in a gas-solid system can be estimated from its heat and mass transfer characteristics, the precision depending upon the accuracy to which the heat and mass transfer characteristics can be predicted, on the complexities of the reaction itself (such as the possibility of homogeneous steps), and on the concentration of the active species present. The prediction of such temperatures in packed beds is considered in Part 2.

Notation

a = coefficient in equation for diffusion coefficient, $D = aT^{3/2}$
A = area, sq.ft.
Cp = heat capacity at constant pressure, B.t.u./(lb. mole)(° F.)
c = constant in Equation (29)
c = concentration, lb. moles/cu.ft.
c' = constant in Equation (28)
d = constant in Equation (29)
D = tube diameter, ft.
d' = constant in Equation (28)
D_i = diffusion coefficient, sq.ft./hr.; D_{AB}, diffusion coefficient of component A through component B; D_{Am}, diffusion coefficient of A through the remaining components in the system
D_T = thermal diffusion coefficient, lb.moles/(hr.)(ft.)
f = Fanning friction factor, dimensionless
f = fraction of hydrogen peroxide in feed decomposed
F = fraction of hydrogen peroxide in feed *not* decomposed, $f + F = 1$
G = mass flow rate, lb./(sq.ft.)(sec.)
h = heat transfer coefficient, B.t.u./(hr.)(° F.)(sq.ft.); h_g, coefficient based on ΔT_g
h' = mole fraction of hydrogen peroxide in stream entering catalyst tube
ΔH = heat of decomposition of hydrogen peroxide, B.t.u./lb. mole
i' = mole fraction of water in stream entering catalyst tube
j_D = mass transfer factor, $(k_G p_{BM} M_M/G)(N_{Sc,f})^{2/3}$, dimensionless
j_H = heat transfer factor, $(h/C_pG)(N_{Pr,f})^{2/3}$, dimensionless; $j_{H'l.m.}$, factor calculated on basis of $\Delta T_{l.m.}$
k = thermal conductivity, B.t.u./(hr.)(sq.ft.)(° F./ft.)
k_c = coefficient of mass transfer, lb.moles/(hr.)(sq.ft.)(lb. mole/cu.ft.)
k_G = coefficient of mass transfer, lb.moles/(hr.)(sq.ft.)(atm.)
K = symbol defined by Equation (39)
l' = symbol in Equation (49), $l' = \phi_A D_{Am} PTK$
L = tube length, ft.
m' = symbol in Equation (49), $m' = \phi_A D_{Am} P(\Delta H)$
M = molecular weight, lb./lb. mole
n = rate of flow of hydrogen peroxide in tube (axial direction), lb. moles/hr.; n_o, initial rate
n' = symbol in Equation (49); $n' = RT^2k$
N = rate of mass transfer, lb.moles/(ft.)^2(hr.); N_i, algebraic sum of rates in complex system
N_{Pr} = Prandtl number, $(Cp\mu/k)$, dimensionless
N_{Re} = Reynolds number; (DG/μ) in tube; dimensionless
N_{Sc} = Schmidt number, $(\mu/\rho D)$, dimensionless
p = partial pressure, atm.; p_{BM}, mean partial pressure of inerts; p', average partial pressure of component i
P = total pressure, atm.
R = gas constant
T = temperature, ° F.; T_w, wall temperature; $T_{w,a}$, average wall temperature; $T_{w,M}$, maximum wall temperature; T_a, average film temperature; ΔT_g, temperature difference across film at point at which the driving force equals $\Delta y_{l.m.}$
u = convection velocity, ft./hr.
U = velocity, ft./hr.
V = molecular volume
w = rate of decomposition, lb.moles/hr.
W = total rate of flow, lb./hr.
x = film thickness, ft.; x_H, effective film thickness for heat transfer; x_D, effective film thickness for mass transfer
y = mole fraction hydrogen peroxide in vapor
α = thermal diffusivity, sq.ft./hr.
Δ = finite difference
μ = viscosity, lb./(sec.)(ft.)
ρ = density, lb./cu.ft.
ϕ = ratio of transport rates, $\phi_A = N_A/N_i$. ϕ is calculable from the stoichiometry of the reaction. Thus

$$\phi_A = a'/(a' + b' - r' - s')$$

where a', b', r', and s' are defined by

$$a'A + b'B \rightarrow r'R + s'S$$

See Wilke (27).

SUBSCRIPTS

a = average
A = component A, referring usually to hydrogen peroxide
B = component B, referring usually to a mixture of steam and oxygen
f = film conditions
i = component i
l.m. = log mean value
M = mean value
s,S = stream conditions
w,W = wall conditions
0 = feed or stream conditions
1 = entrance of tube
2 = exit of tube
P = products
R = reactants

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analysis of rotary dryer and cooler performance

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Although satisfactory procedures for the design and the correlation of performance of rotary dryers have been developed empirically, the fundamental factors and relations governing performance and dryer scale-up have not been completely analyzed.

Rotary dryers and coolers consist of cylindrical shells that rotate on a nearly horizontal axis and through which air and material may be passed cocurrently or countercurrently. The interior surface of the shell is usually fitted with flights to elevate the material and to permit it to cascade through the air stream. There are eleven prominent and independent variables in this system: (1) character, (2) rate, and (3) temperature of the material; (4) rate and (5) temperature of the air or gas; and (6) diameter, (7) length, (8) slope, (9) rate of rotation, (10) flight capacity, and (11) number of flights of the dryer. All these affect heat transfer in the dryer, and all except the air and material temperature affect dryer hold-up and time of passage. In view of the similarity between rotary drying and cooling, the ensuing discussion of rotary drying will also pertain to rotary cooling insofar as applicable.

The most notable studies on the theoretical aspects of dryer performance and scale-up reported in the technical literature are those of Miller, Smith and Schutte (6); Prutton, Miller and Schutte (9); and Friedman and Marshall (3 and 4). These studies accounted only partially for the first-order effects of the eleven-variable rotary-dryer system on heat transfer and hold-up.

For heat transfer Miller et al. used the following equations to summarize the results of their work:

$$Q/t = 0.374\ LD[(N-1)/2]G^{0.67}\Delta T_m \quad \text{(for } N = 6\text{)}$$

$$Q/t = 0.104\ LD[(N-1)/2]G^{0.80}\Delta T_m \quad \text{(for } N = 12\text{)}$$

where

- Q/t = heat transfer rate, B.t.u./hr.
- L = dryer length, ft.
- D = dryer diameter, ft.
- N = number of flights
- G = air rate, lb./(hr.)(sq.ft.)
- ΔT_m = log mean temperature difference, ° F.

In view of the small size of their experimental unit (8 in. in diam.) and the variation in the constants of their equation in going from six to

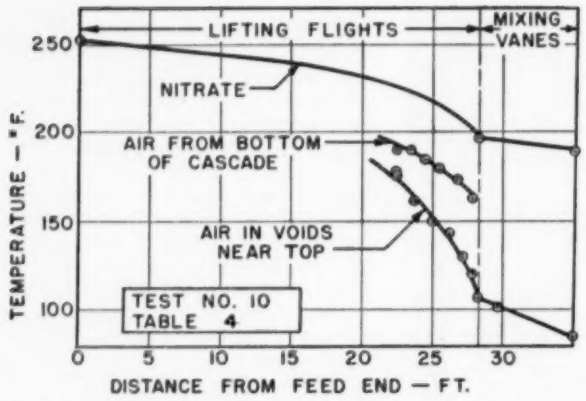

Fig. 1. Air and material temperatures measured in a 6-ft.-diam. rotary cooler for countercurrent operation.

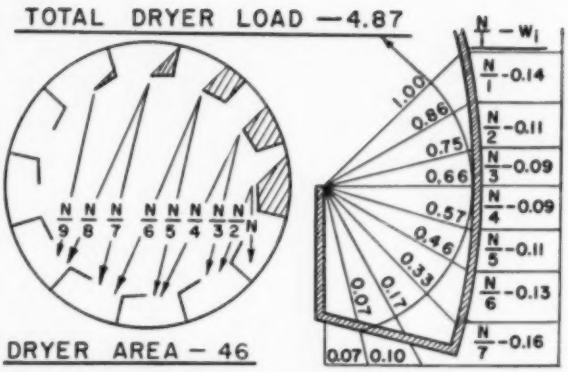

Fig. 2. Trajectories used for analyzing transport of material through rotary dryers.

twelve flights, there is no assurance that the formula suggested yields consistent correlations of performance over a six- to tenfold range of the diameter as encountered in plant practice. Their formula also fails to account for variations in heat transfer due to variations in dryer hold-up.

Friedman and Marshall (*4*) extended the work on correlation of rotary-dryer performance sufficiently to show that dryer hold-up exerted a dominant effect on heat transfer. Their studies were confined largely to tests made in a 1-ft.-diam. test unit. Most of their results were shown in graphical form and very little effort was made to elucidate the actual mechanism of heat transfer in rotary dryers. As a basis for scale-up they suggested the use of a volumetric heat transfer coefficient multiplied by the reciprocal of the diameter. Adoption of this basis appears somewhat arbitrary and was not fully vindicated experimentally.

For time of passage, the prior correlations were usually modeled after the empirical kiln equation published by Sullivan, Maier and Ralston (*12*) in 1927. The form suggested for dryers is

$$t = \frac{kL}{DR\phi} \pm mv \text{ or } t = \frac{kL}{DR^n\phi} \pm mv$$

Subsequent analysis of the kiln relation by Pickering, Feakes, and Fitzgerald (*8*) and by Saeman (*10*) disclosed only superficial justification for this choice. The published relations for dryers are deficient primarily in that interacting effects among the diameter, rate of rotation, slope, hold-up, and air velocity are not recognized. Because of this deficiency, values of the constants *k,m* and *n* in the equation above hold only for relatively narrow ranges of experimental conditions and are hardly valid for the tenfold range of diameters encountered in practice.

As the eleven-variable dryer system is admittedly a complicated system to analyze completely, the rational basis for simplification of this system is (1) to elucidate the mechanics of heat transfer and material transport, thereby expressing one or more variables as functions of the others to reduce the number of independent variables and (2) to express the relations sought in terms of first-order effects between the dominant variables only. Application of these two principles to the rotary-dryer system constitutes the objective of this paper.

Mechanism of Heat Transfer

The main controlling relation for heat transfer was found to be the material-cascade rate from the flights and the air-material entrainment ratio of the cascading streams. No major effects involving surface area directly were identified within the range of particle sizes tested; however, for very fine or coarse particles, minor effects due to exposed surfaces were observable. It is believed that horizontal air flow in the dryer is confined chiefly to the voids between the cascading material. Air is entrained with the falling material, compared with which the mass of entrained air is small and therefore reaches rapid temperature equilibrium with the surface of the material. From the bottom, the heated air diffuses again into the voids between the cascading curtains to repeat the cycle. This hypothesis was verified experimentally by measuring top and bottom temperatures in a 6-ft.-diam. plant cooler as shown in Figure 1. It is seen that the bottom temperatures are consistently hotter than the top temperatures. The top temperatures, corresponding to the highest rate of air flow, yield the best heat balance with the material. Since the top temperatures are also expected to exert the dominant effect on the heat transfer rate, it is seen that Friedman and Marshall were justified in basing their heat transfer coefficient on calculated air temperatures in view of the fact that they reported difficulty in measuring consistent air temperatures in their experimental dryer. The difference in the bottom air and material temperatures is accounted for by the fact that the air comes to temperature equilibrium only with the surface of the material owing to the short time of exposure on each cascade. Air-temperature measurements in cascading streams confirmed the fact that the major fraction of heat interchange occurred within 1 to 2 ft. from the origin of the cascade.

From this viewpoint, the primary factors which determine the rate of heat transfer are material-cascade rate, which is a function of the size and number of flights, the hold-up, and the rate of rotation; and the air-material entrainment ratio, which is primarily a function of flight size with possible secondary effects from rate of rotations and serrations in the lips of the flights, if used. Effects from other variables, such as the particle-size of the material, air velocity, staggering of flights, etc., except in extreme cases, appear to be only of minor significance.

Alternative cases of dryer operation for which this mechanism of heat transfer is inapplicable are conditions of operation for which distribution of material in the dryer is sufficiently uniform to obliterate the voids completely, thereby forcing the air to flow through the suspended material; and operation with sticky or lump material where there are no well-defined streams of cascading material to entrain air. In the former case, unusually high heat transfer coefficients may be anticipated, and the latter conditions would result in excessively low heat transfer capacity.

Mechanism of Material Transport

Material transport through rotary dryers was analyzed in terms of incremental transport rates associated with individual cascade paths in the dryer to yield a transport-rate distribution function similar in form to experimentally observed variations in time of passage. From this distribution function

suitable constants may readily be selected for calculating time of passage to compensate for effects of hold-up.

The scheme of analysis is shown in Figure 2. For each path, designated by index i, the horizontal displacement by cascade for countercurrent operation is

$$X_i = S_i\phi - f(S_i,v) \quad (1)$$

where

X_i = horizontal displacement by cascade for path i
S_i = length of path i
ϕ = slope of dryer
v = air velocity
$f(S_i,v)$ = drift due to air flow

Considering only first-order effects, the air drift may be presumed proportional to S_i and v yielding

$$f(S_i,v) = mS_iv \quad (2)$$

where

m = constant

or if Equations (1) and (2) are combined,

$$X_i = S_i(\phi - mv) \quad (3)$$

The transport velocity and time associated with each path are therefore

$$V_i = R(N/i)S_i(\phi - mv) \quad (4)$$

and

$$t_i = L/V_i \quad (5)$$

where

V = transport velocity
t = transport time
R = rate of rotation
N/i = number of cascades a revolution
N = number of flights
i = index equal to number of flights skipped by each successive path
L = length of dryer

The material-transport rate for each path is the product of the transport velocity and the weight of material W_i associated with each path, or W_iV_i. The average time of passage is therefore

$$t = \frac{H}{\Sigma W_iV_i} \quad (6)$$

Values of W_i, V_i and t_i calculated from measurements shown in Figure 2 are tabulated in Table 1. The product W_iV_i plotted against t_i, as shown in Figure 3, gives the variation in time of passage for material in rotary dryers. The scheme of calculation results in a bar graph which may be converted to a continuous curve enclosing the same area. The time of passage calculated from the rotary kiln formula

$$t = \frac{L\sin\theta}{\pi R\phi D} \quad (7)$$

is used as the starting point of the distribution curve, as some of the material in fully loaded dryers actually progresses by kiln action. The shape of the distribution curve is confirmed by data reported by Smith (*11*) reproduced in Figure 4.

In view of the two dominant peaks in the curve, simplification of Equations (4) and (5) may readily be achieved by grouping all trajectories belonging to the first and second peaks. The product of the factors $R(N/i)S_i$ is simply the distance cascaded by the material for the unit time. For the first peak this distance is approximately πDR and that for the second peak corresponds roughly to material cascading across the center, or $2DR$. The time of passage for rotary dryers is therefore expected to range from

$$t_\pi = \frac{L}{\pi DR(\phi - mv)} \quad (8)$$

for heavily loaded dryers having small flights to

$$t_2 = \frac{L}{2DR(\phi - mv)} \quad (9)$$

for lightly loaded dryers.

Table 1.—Calculated Variation of the Material-Transport Rate Through Rotary Dryers

(Based on relative cross-sectional areas from Figure 2)

N/i	S_i*	Relative velocity, $V_i = (N/i)S_i$	Relative time, $t_i = 3/V_i$	W_i	W_iV_i
....	.....	4.4†	0.7†	....	....
12/1	0.25D	3.0	1.0	0.14	0.42
12/2	0.5D	3.0	1.0	0.11	0.33
12/3	0.6D	2.4	1.2	0.09	0.22
12/4	0.7D	2.1	1.4	0.09	0.19
12/5	0.8D	1.9	1.6	0.11	0.21
12/6	0.9D	1.8	1.7	0.13	0.23
12/7	0.9D	1.5	2.0	0.16	0.24
12/8	0.8D	1.2	2.5	0.10	0.12
12/9	0.7D	0.9	3.3	0.07	0.06

* Length of trajectory relative to diameter D, Figure 2.
† Ratio of kiln time to minimum dryer time equals $\sin\theta(\theta = 45°)$.

Experimental Results on Heat Transfer

Information for the experimental corroboration of the mechanism of heat transfer and hold-up proposed in this paper is drawn from operating data of coolers and dryers ranging from 1 to 11 ft. in diam. as well as from published data in the literature.

Of all the variables involved in heat transfer studies, the most difficult to ascertain with accuracy is the air temperature. Instances were encountered where even minor radiation errors in the air-temperature measurement might result in two- or threefold differences in size of the heat transfer coefficient, and in several instances trends in the value of the heat transfer coefficient were traceable to a systematic radiation error in the measured air temperature (temperature measurements by bare thermocouple) as operating conditions, such as the air rate, were varied. This situation was also recognized and discussed in considerable detail by Friedman and Marshall (*4*). Data from Furnas (*5*) indicate the need for an air velocity of about 20 ft./sec. to reduce radiation errors to negligible proportions.

Precautions taken to reduce to a minimum the effects of radiation errors on heat transfer coefficients were (1) all

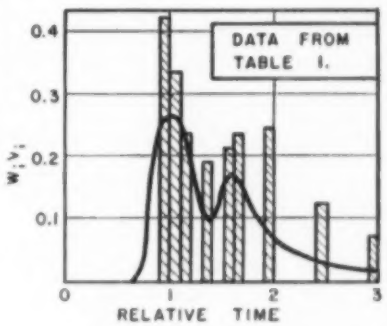

Fig. 3. Calculated variation of material-transport rate through rotary dryers.

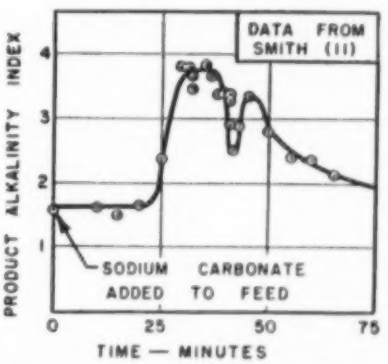

Fig. 4. Experimental variation of material-transport rate through rotary dryers.

critical temperature measurements were made with a shielded, high-velocity thermocouple using at least 20 ft./sec. air velocity; (2) air temperatures were checked for heat balance with the material; (3) smooth exponential curves were drawn through the air and material temperature points to average the local variations between measurements; and (4) heat transfer coefficients were usually calculated over that part of the dryer or cooler which accounted for the major portion of the total heat transferred. In some cases it was not unusual to encounter 90% of the heat transferred in 10% of the dryer or cooler. The validity of these precautions (shielded thermocouples excepted) ties in directly with the derivation of the log-mean-temperature difference and will be found to apply (a) if the heat transfer coefficient is uniform over the test section, (b) if the heat capacities of the air and material remain essentially constant, and (c) if the heat transfer rate is proportional to the temperature difference (*1*). Since the observed air- and material-temperature points fell on essentially exponential curves, the validity of the use of heat transfer coefficients calculated from the log-mean-temperature difference and the precautions adopted to minimize the effects of radiation errors on this calculation may be accepted. If these conditions are not met for the entire dryer, the length may be subdivided into a series of sections each corresponding approximately to the conditions required for the validity of the log-mean-temperature (*2*).

Additional justification for restricting heat transfer correlations to sections of the dryer accounting for most of the heat transfer is the minimizing of the effects of shell-heat loss on the correlation. From an over-all heat balance, shell losses for a 6-ft. plant cooler amounted to 12% of the heat input; however, by restricting the section for heat transfer study to 5 ft. at the discharge end, in which over half of the cooling occurred, the relative magnitude of heat loss to heat transferred dropped to about 5%. As shell losses are highly variable, depending on temperature and dryer design, no effort was made in this study to integrate shell losses with internal heat transfer. Other means used to minimize effects of shell losses on the heat transfer correlation were to use insulated equipment and to operate experimental equipment near room temperature to reduce heat losses.

Correlation of the heat transferred vs. the material-cascade rate may be made on either a weight or a volume basis. In view of the postulated mechanics of heat transfer the volumetric basis appears to be least affected by variations in bulk density of material. It was therefore adopted as a basis of correlation. The volumetric cascade rate is given by the relation

$$C = ANR \qquad (10)$$

The flight load is measured at the point where material begins to cascade. For a fully loaded dryer this point may arbitrarily be taken near the horizontal axis through the dryer cross section. For convenience the cascade and heat transfer rates may be normalized to a unit length of dryer as the effect of length on both heat transfer capacity and transport time is not significantly interrelated with the other variables involved. The heat transfer coefficient is therefore given in terms of B.t.u./(min.)(ft.)(° F.) and the cascade rate has the units cu.ft./(min.)(ft.). The ratio between these two factors designates the B.t.u./(cu.ft.)(° F.) of heat transferred and is the product of the specific heat of air [B.t.u./(lb.)(° F.)] and the air-material entrainment ratio (lb. air/cu.ft. material). Designated the cascade heat transfer factor, it is equal to the slope of the curve for plots of the heat transfer coefficients vs. cascade rate. All factors are dimensionally compatible so that any consistent set of units may be used.

Data for heat transfer studies on dry granular ammonium nitrate in an insulated experimental dryer 1 ft. in diam. and 8 ft. long are summarized in Tables 2 and 3 covering operation at 5 and 35 rev./min., respectively. Heat transfer coefficients vs. cascade rates for these tests are plotted in Figure 5. The coefficients for 5 rev./min. fall in a well-defined band corresponding to 2.2 B.t.u./

Table 2.—Heating Ammonium Nitrate with Air in a 1-Ft.-Diam. by 8-Ft. Rotary Dryer

(12 flights;* 5 rev./min.; −16-, +20-mesh material; countercurrent air flow)

Test	Rates, lb./min. Nitrate	Air	Dryer hold-up, lb./ft.	Test † section of dryer, ft.	Terminal temperatures of section, ° F. Nitrate Feed	Nitrate Product	Air Exit	Air Inlet	Log mean difference, ° F.	Sectional heat balance, B.t.u./min. Nitrate	Air	Heat transfer ‡ coefficient, B.t.u./(min.)(ft.)(° F.)	Cascade ** rate, cu.ft./(min.)(ft.)
Slope = 0.05 ft./ft.; air velocity = 2 ft./sec.													
1	2.0	7.3	4.5	0–2	76	82	81	84	3.2	5	5	0.8	0.7
2	3.1	7.3	5.5	0–1	75	77	77	78	1.4	2	2	1.4	1.2
3	4.2	7.3	6.9	6–8	105	133	109	153	10.0	48	77	2.4	1.6
4	7.1	7.3	9.4	6–8	97	124	101	147	10.9	77	81	3.5	1.6
Slope = 0.067 ft./ft.; air velocity = 2 ft./sec.													
5	1.2	7.3	1.5	0–2	78	92	88	94	5.0	7	9	0.7	0.2
6	3.0	7.3	5.4	6–8	93	127	99	136	7.3	41	65	2.8	1.0
7	5.0	7.3	6.9	6–8	67	95	71	110	8.3	56	68	3.4	1.6
8	5.0	7.3	7.4	6–8	92	119	96	130	7.0	54	59	3.9	1.6
9	10.0	7.3	11.3	6–8	113	137	116	173	13.3	100	100	3.7	1.6
10	10.0	7.3	10.9	7–8	130	146	139	173	16.4	60	60	3.8	1.6
Slope = 0.067 ft./ft.; air velocity = 3 ft./sec.													
11	1.6	10.6	2.9	0–2	85	95	92	97	4.0	6	13	0.7	0.4
12	2.8	10.6	5.7	0–2	78	81	80	82	1.4	3	5	2.1	1.2
13	2.9	10.6	5.0	0–1	79	83	82	84	1.8	5	5	2.8	0.8
14	3.9	10.6	7.4	6–8	109	138	115	151	9.1	46	92	2.5	1.6
15	5.0	10.6	7.7	6–8	120	135	122	141	3.6	30	50	4.2	1.6

* Cross section of flight shown in Figure 6A.
† Test section measured from feed end of dryer.
‡ Heat transfer coefficient based on heat gained by nitrate.
** Derivation of cascade rate given in text. Bulk density of ammonium nitrate—60 lb./cu.ft.

(cu.ft.)(° F.); those for 35 rev./min. fall in a band corresponding to a heat transfer factor of 1.4 B.t.u./(cu.ft.)(° F.). This shift in the heat transfer factor is presumed to be due to a decrease in the air-material entrainment ratio associated with an increase in the density of the cascading streams at the higher speed. Variations in air rate (fivefold) and feed rate (fifteenfold) show no significant first-order effects distinct from the relations of these variables with the cascade rate. A twofold variation in particle size at 35 rev./min. exhibited at most a second-order effect in this correlation, but since effects of this order are largely obscured by variability within limits of experimental error, no detailed analysis of effects due to variation in surface area was undertaken.

For low-speed operation the cascades were well-defined, and cascade rates were derived from Equation (10) using flight A in Figure 6. For high-speed operation twelve short radial flights 1-in. deep were used, and the cascade pattern was determined largely by the kinetics of the material at the speed of rotation. The 35 rev./min. rate was used to provide reasonably uniform distribution of material over the dryer cross section. The material cascaded approximately twice a revolution, and the cascade rate C was therefore assumed to be

$$C = 2HR \qquad (11)$$

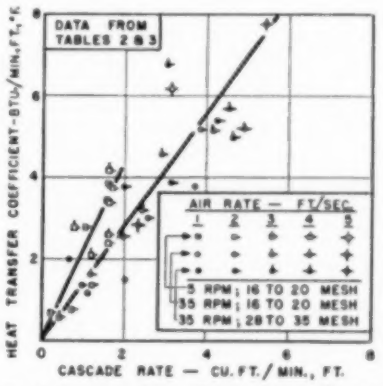
DATA FROM TABLES 2 & 3
HEAT TRANSFER COEFFICIENT-BTU/MIN.,FT.,°F.
CASCADE RATE — CU. FT./MIN., FT.
AIR RATE — FT/SEC.
1 2 3 4 5
5 RPM; 16 TO 20 MESH
35 RPM; 16 TO 20 MESH
35 RPM; 28 TO 35 MESH

Fig. 5. Heat transfer coefficient vs. cascade rate in a 1-ft.-diam. by 8-ft. dryer for ammonium nitrate.

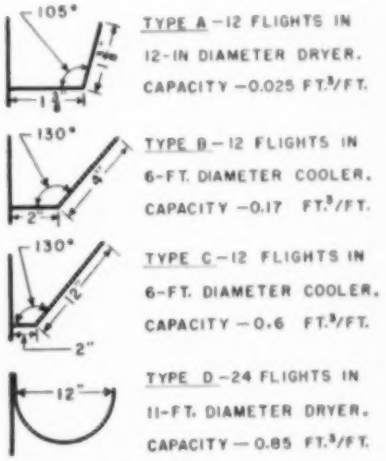
105°
TYPE A — 12 FLIGHTS IN 12-IN DIAMETER DRYER. CAPACITY — 0.025 FT.³/FT.
130°
TYPE B — 12 FLIGHTS IN 6-FT. DIAMETER COOLER. CAPACITY — 0.17 FT.³/FT.
130°
TYPE C — 12 FLIGHTS IN 6-FT. DIAMETER COOLER. CAPACITY — 0.6 FT.³/FT.
TYPE D — 24 FLIGHTS IN 11-FT. DIAMETER DRYER. CAPACITY — 0.85 FT.³/FT.

Fig. 6. Dryer and cooler flight dimensions.

Table 3.—Heating Ammonium Nitrate with Air in a 1-Ft.-Diam. by 8-Ft. Rotary Dryer

(12 flights;* 35 rev./min.; slope, 0.067 ft./ft.; countercurrent air flow)

Test	Rates, lb./min. Nitrate	Air	Dryer hold-up, lb./ft.	Particle size of material, mesh	Test † section of dryer, ft.	Terminal temperatures of section, ° F. Nitrate Feed	Nitrate Product	Air Exit	Air Inlet	Log mean difference, ° F.	Sectional heat balance, B.t.u./min. Nitrate	Air	Heat transfer‡ coefficient, B.t.u./(min.)(ft.)(° F.)	Cascade ** rate, cu.ft./(min.)(ft.)
Air velocity = 1 ft./sec.														
1	5	3.6	0.9	−16+20	6-8	77	99	85	135	18.7	44	45	1.2	1.1
2	5	3.6	0.6	−28+35	7-8	93	105	99	127	12.3	24	25	2.0	0.7
3	10	3.6	1.7	−16+20	6-8	84	94	87	131	13.6	40	40	1.5	2.0
4	15	3.6	3.1	−16+20	6-8	94	100	95	135	9.5	36	36	3.8	3.7
Air velocity = 2 ft./sec.														
5	5	7.2	0.9	−16+20	6-8	103	117	110	131	10.1	28	35	1.4	1.1
6	5	7.2	1.6	−28+35	6-8	108	126	115	138	9.3	36	37	3.8	1.9
7	10	7.2	2.1	−16+20	6-8	94	110	97	134	10.1	64	64	3.1	2.5
8	10	7.2	2.4	−28+35	7-8	106	117	110	136	11.2	44	44	3.9	3.1
9	15	7.2	3.2	−16+20	7-8	96	109	100	147	15.1	78	80	5.2	3.8
10	15	7.2	3.5	−28+35	7-8	96	103	98	123	7.8	42	43	5.4	4.2
Air velocity = 3 ft./sec.														
11	5	10.3	1.0	−16+20	6-8	99	115	110	126	11.0	32	40	1.5	1.2
12	10	10.3	2.1	−16+20	7-8	88	103	104	128	19.5	60	60	3.1	2.5
13	10	10.3	2.5	−28+35	7-8	110	119	112	130	5.3	36	45	6.8	3.0
14	15	10.3	3.4	−16+20	7-8	105	115	110	137	11.5	60	62	5.2	4.1
15	15	10.3	3.8	−28+35	6-8	96	108	98	129	8.1	84	78	5.0	4.6
Air velocity = 4 ft./sec.														
16	5	14.3	1.6	−16+20	6-7	100	105	105	108	3.9	10	10	2.6	1.9
17	10	14.3	2.4	−16+20	6-8	109	127	115	137	7.8	72	75	4.6	2.9
18	15	14.3	4.1	−16+20	6-8	110	122	113	135	6.9	72	75	5.2	4.9
19	15	14.3	3.8	−28+35	7-8	94	105	101	122	11.6	66	65	5.7	4.5
Air velocity = 5 ft./sec.														
20	5	18.0	1.9	−16+20	0-2	87	93	91	94	2.1	12	13	2.9	2.3
21	10	18.0	2.6	−16+20	6-8	95	104	97	108	2.9	36	47	6.2	3.1
22	15	18.0	4.5	−16+20	7-8	104	115	110	126	8.3	66	69	7.9	5.4

* Radial flights, 1 in. high.
† Test section measured from feed end of dryer.
‡ Heat transfer coefficient based on heat gained by nitrate.
* Derivation of cascade rate given in text. Bulk density of ammonium nitrate—60 lb./cu.ft.

The maximum attainable cascade rate for 5 rev./min. operation was 1.6 cu.ft./(ft.)(min.); that for 35 rev./min. was proportionately greater with no precisely defined maximum limit. Although significantly higher heat transfer coefficients were realized for high-speed operation, the time of passage was so short that conditions were generally inconsistent with other drying requirements demanding a longer retention time. However for cooling, where holding time may not be critical, the use of high heat transfer coefficients permits sizable reductions in the length of the cooler.

Variation of the cascade rate in the current tests was achieved by varying the feed rate, slope, air velocity, and speed. The alternative of varying the cascade rate by changing the number of flights was not investigated. Friedman and Marshall (*4*) show that the heat transfer coefficient diminishes with fewer flights, as anticipated, but the significance of this effect is partially obscured in their tests because of abnormally high heat losses (20 to 50% heat loss reported).

Performance data for operation of a 6-ft.-diam. cooler for granular ammonium nitrate are summarized in Table 4. The cooler was not insulated except for a dust coating of variable thickness on the inside which lowered heat loss through the shell. Heat loss amounted to 12% of the total input, based on material. The operation was tested with two sizes of flights differing by a factor of 4 with respect to maximum carrying capacity, as illustrated by types *B* and *C* in Figure 6. The heat transfer factor at full flight loading for the larger was roughly 0.9 of that for the smaller and was about one third that for 5 rev./min. operation in the 1-ft. dryer. Operation with an underloaded cooler using flight *C* apparently resulted in an additional reduction of the heat transfer factor, believed to result from ineffective distribution of material across the cooler, which thereby allowed some of the air to flow through without becoming effectively mixed with the material.

If length of the cascade had any appreciable effect on the heat transfer rate, the heat transfer factor would tend to increase as the diameter increased but, as was indicated earlier, separate exploratory air-temperature measurements in a falling stream indicate that the major fraction of heat is transferred within 1 to 2 ft. of the point of origin. At least in larger sizes the possible increase in heat transfer resulting from longer contact time appears to be overshadowed by the lower air-material entrainment ratio associated with larger flight to yield very little net change in the heat transfer factor. The most significant results in this respect are those

Table 4.—Operating Data for Plant-Size Coolers and Dryers for Ammonium Nitrate *

Test	Rates, lb./min.		Dryer hold-up, lb./ft.	Test † section of dryer, ft.	Terminal temperatures of section, ° F.				Log mean difference, ° F.	Sectional heat balance, B.t.u./min.		Heat transfer ‡ coefficient, B.t.u./(min.)(ft.)(° F.)	Cascade ** rate, cu.ft./(min.)(ft.)	Heat transfer ** factor, B.t.u./(° F.)(cu.ft.)
	Nitrate	Air			Nitrate Feed	Nitrate Product	Air Exit	Air Inlet		Nitrate	Air			
6-ft.-diam. by 35-ft. countercurrent rotary cooler;¶ 12–0.17 cu.ft./ft. flights (Fig. 6B); 4.8 rev./min.; slope = 0.067 ft./ft.														
1	350	414	40–60§	5–28	217	140	167	41	72	14,700	12,500	8.9	9.7	0.92
2	580	432	60–80	5–28	255	200	195	84	85	13,900	11,500	7.1	9.7	0.73
3	646	424	80–100	5–28	247	202	206	76	76	12,300	13,200	7.1	9.7	0.73
4	700	372	80–100	5–28	254	205	203	63	87	14,700	12,500	7.4	9.7	0.76
5	700	372	80–100	5–28	252	203	201	61	89	14,700	12,500	7.2	9.7	0.74
6	700	374	80–100	5–28	241	190	195	56	88	15,300	12,500	7.6	9.7	0.78
6-ft.-diam. by 35-ft. countercurrent rotary cooler;¶ 12–0.6 cu.ft./ft. flights (Fig. 6C); 4.8 rev./min.; slope = 0.067 ft./ft.														
7	550	400‖	132	23–28	201	182	153	110	59	4,180	.....	14.2	27	0.53
8	550	400	132	23–28	213	190	168	115	59	5,060	.....	17.2	27	0.64
9	600	360	166	23–28	222	198	174	107	67	5,760	.....	17.2	32	0.54
10	700	411	176	23–28	213	193	175	118	55	5,600	.....	20.4	37	0.55
11	700	400	176	23–28	210	188	133	120	44	6,050	.....	27.5	37	0.74
11-ft.-diam. by 42-ft. cocurrent rotary dryer; †† 24–0.85 cu.ft./ft. flights (Fig. 6D); 3.0 rev./min.; zero slope ‡‡														
12	720	1350‖	.....	2–20	110	151.8	154.0	217	26	20,200	.....	43.0	61	0.70
13	970	1460	.....	2–20	115	149.0	151.0	215	25	23,500	.....	52.0	61	0.85

* Particle size predominantly —16+35 mesh; bulk density 60 lb./cu.ft.
† Test section measured from feed end of dryer.
‡ Heat transfer coefficient based on heat lost or gained by nitrate.
** Derivation of cascade rate and heat transfer factor given in text.
¶ Cooler fitted with helical vanes 0–5 ft; lifting flights 5–28 ft.; and mixing vanes 28–35 ft.
§ Estimated from bed depth. Cooler overloaded; only 35 lb./ft. required for full-flight loading.
‖ Air flow from material rates by heat balance.
†† Dryer fitted with lifting flights 2–20 ft. only. Shell insulated with 2 in. of rock wool.
‡‡ Material transport by cocurrent air flow and internal material gradient.

from an 11-ft.-diam. insulated dryer for granular ammonium nitrate having twenty-four flights, as illustrated by type D, Figure 6, and capable of holding 0.85 cu.ft./ft. fully loaded. The heat transfer factor in this case was nearly equal to that for the 6-ft. cooler.

The experimental results of Friedman and Marshall are generally consistent with the conclusions advanced in this paper. Their work is notable for the wide variety and size range of materials tested. For a fifteenfold decrease in size (2,300 to 150μ), the heat transfer factors for sand calculated from their data increase from 0.8 to 1.3 B.t.u./(cu.ft.)(° F.), a range consistent with the factors reported for granular ammonium nitrate. The increase for fine material is believed to be due to the fact that closer equality is attainable between the average temperature and surface temperature during cascade for fine material than for coarse particles; however the magnitude of this effect on the heat transfer factor is small compared with the fifteenfold variation in size.

In view of the experimental demonstrations cited, the postulated mechanism of heat transfer serves to unify a mass of diversified qualitative and quantitative information on rotary dryer and cooler operation. It has been shown that the primary variables such as diameter, speed, size and number of flights, slope, particle size, air rate, and feed rate affect the heat transfer capacity mainly insofar as these variables affect the cascade rate. The effects of countercurrent vs. cocurrent operation and of heating vs. cooling were not explicitly demonstrated, but aside from the effects of the former on hold-up no other major effects from these sources are deducible from the proposed mechanism of heat transfer.

The proposed methods of correlation are consistent with the conclusions of Friedman and Marshall in that the heat transfer coefficient varies with hold-up insofar as does the cascade rate. No basis was found for suspecting increases in heat transfer capacity beyond the hold-up corresponding to optimum dryer loading. Although this situation was indicated by some of the results plotted by Friedman and Marshall (*4*), it was not consistently shown on all their heat transfer vs. hold-up curves. Reexamination of their results indicates that in most instances a break at the point of full flight loading would be appropriate.

The sum total of information on heat transfer coefficients for low-speed operation with fully loaded flights, tabulated in Tables 2, 3, and 4, can be condensed formally as

$$\frac{Q}{tL\Delta T_m} = C(0.6 + 2.5e^{-4.8M}) \qquad (12)$$

where

$\frac{Q}{tL\Delta T_m}$ = heat transfer coefficient, B.t.u./(min.)(ft.)(° F.)

As this is given only as a summary formula, it is not intended as a general basis for extrapolation outside the range of variables from which is was derived.

For dryer scale-up some of the variables affecting heat transfer, such as diameter, speed of rotation, size and number of flights, may be consolidated by assuming constant ratios between them and thereby reducing the number of independent design variables. Referring to Equations (10) and (12), it becomes evident that for constant dryer cross-sectional geometry, the heat transfer coefficient may be represented as a direct function of the diameter. Assuming constant cross-sectional geometry and constant rate of rotation, the cascade rate and the heat transfer coefficient will vary approximately as D^2. On the other hand, if the peripheral shell speed is held constant, the cascade rate and heat transfer coefficient will increase only in direct proportion to D. Miller, Smith, and Schutte (*6*) as well as Friedman and Marshall (*4*) concluded that the heat transfer coefficient, based on a unit length of dryer, should vary in direct proportion to D. The accessory conditions for ensuring the validity of extrapolations over a wide range not being given in the prior literature, the results of this work serve to establish a rational basis for rotary dryer and cooler scale-up on firmer ground.

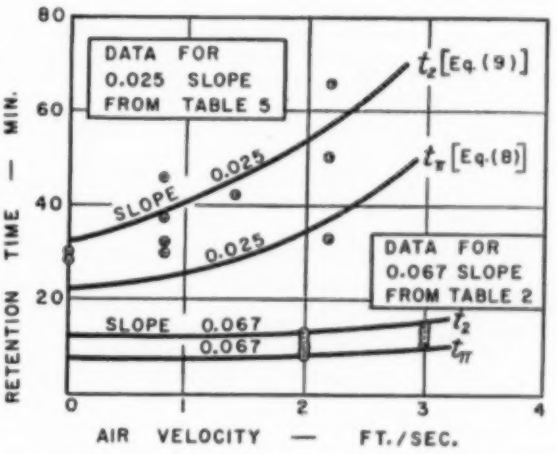

Fig. 7. Observed and calculated retention time of ammonium nitrate in a 1-ft.-diam. rotary dryer. Hold-up for retention time t_2 one half to one third that for t_π.

Experimental Results on Hold-up

The material transport rate through rotary dryers is usually given in terms of average retention time or hold-up. These two factors are related as follows:

$$H = Ft$$

where

H = hold-up
F = feed rate
t = average retention time

The hold-up of a dryer can be measured accurately, but the actual transport time varies widely, as indicated earlier.

The average retention time in a 1-ft.-diam. dryer for 5 rev./min. operation was determined for slopes ranging from 0.025 to 0.067 ft./ft. and for air velocities ranging from 0 to 3 ft./sec. Primary data for these tests are tabulated in Tables 2 and 5 and are plotted in Figure 7. For most of the tests the position of the average time between t_π and t_2 calculated from Equations (8) and (9) varied consistently with the hold-up. For fully loaded flights, corresponding to a hold-up of 9 to 10 lb./ft., the time corresponded nearly to t_π but for hold-ups one half to two thirds the full load value the average time corresponded more nearly to t_2. Effects of air velocity on the average time of passage were adequately represented by setting m equal to 0.005 for v expressed in ft./sec. for −16- +20-mesh material. This same constant was also applicable for 35 rev./min. operation in the 1-ft.-diam. dryer and for the tests made in the 6-ft.-diam. plant cooler. The constant m is an empirical coefficient varying with the character of material and must be determined experimentally for different materials.

Hold-up measurements for various feed rates and air rates at 35 rev./min. in the 1-ft.-diam. dryer are summarized in Table 3 and plotted in Figure 8. For these tests the material cascaded in a broad band diagonally across the center of the dryer. The data are summarized nicely by the formula

$$H/L = \frac{F}{2.4DR(\phi - 0.005v)} \qquad (13)$$

where H/L is the hold-up per unit length.

The factor 2.4 indicates that the material cascaded about 2.4 times a revolution, or that the cascading band traversed the dryer somewhat in advance of the center. As the position of the cascade changes with speed in the "high-speed" range of operation, this numerical factor associated with the diameter must be chosen accordingly to indicate the total cascade distance a revolution.

Calculated and observed values of hold-up for the 6-ft.-diam. cooler are tabulated in Table 5. Measurements are shown for the larger flight size only because the cooler was heavily overloaded at all times for operation with the smaller flight. The data are summarized by using 2.6 as the cascade factor, or

$$H/L = \frac{F}{2.6DR(\phi - 0.005v)} \qquad (14)$$

For these tests the cooler hold-up was slightly less than optimum, or full loading, and so some of the trajectories corresponding to the first peak were inactive.

From the foregoing cases it is evident that the proposed mechanism of material transport in rotary dryers provides a satisfactory rational basis for estimating coefficients to account for the effect of both hold-up and air velocity on the average retention time. If the air-velocity term is disregarded, the arrangement of the remaining factors of the proposed retention-time formula agrees in form with earlier published relations. With respect to rate of rotation, Friedman and Marshall (*3*) proposed the use of $R^{0.9}$ instead of R to account more accurately for effects on transport time

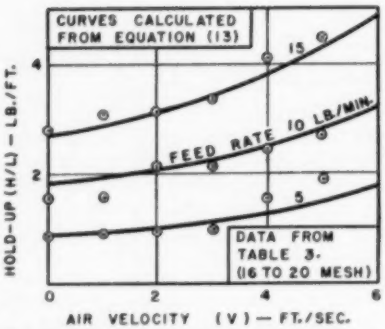

Fig. 8. Effect of air velocity on hold-up in a 1-ft.-diam. dryer for countercurrent operation.

encountered at higher speeds. This is acceptable from an empirical viewpoint, but practically the allowance for the influence of speed on the trajectories can be made directly on the factor which designates the total distance of fall of the material a revolution, as was done for test operation at 35 rev./min. The nonlinear increase on time of passage with speed detected by Friedman and Marshall results from the fact that the time of fall, assumed negligible for slow rotation, becomes more significant at higher rates, and the number of cascades a revolution decreases as the rate of rotation is increased because the trajectories deviate more from the vertical.

Rational Basis for Dryer Design

Dryer design covers the steps required to derive an essentially complete interrelation among the eleven variables involved to satisfy specific performance requirements. Variables such as the material character, rate, and temperature are usually given in the initial statement of the problem. Air rates and temperatures may be determined by heat and material balances. The character of the material dictates the drying time, from which dryer hold-up and all other variables that characterize the dryer are derived.

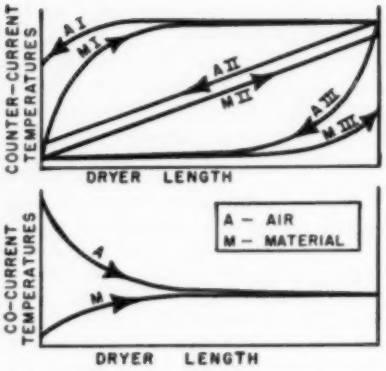

Fig. 9. Typical air-, material-temperature profiles for rotary dryers.

Material-drying rates are dictated by the time-temperature profile of the material in the dryer, which in turn may be controlled by varying the ratio of the heat transfer capacity of the air relative to that of the material and by using counter- or cocurrent air flow. There are three general types of profiles for countercurrent and one for cocurrent operations, as shown in Figure 9. If the air heat transfer capacity is in excess of that for the material (case I countercurrent), the major fraction of heat transfer occurs in the feed end of the dryer, a situation that leads to efficient drying conditions as the material is exposed to relatively hot gas throughout its residence in the dryer. If the material heat transfer capacity exceeds that of the air (case III countercurrent), the heat transfer is concentrated into the discharge end of the dryer and thus leads to ineffective use of the equipment and in some cases to condensation of moisture from the air by contact with cool feed material. Conditions in which the heat transfer capacity for the air and material are nearly in balance (designated as case II, countercurrent) lead to a relatively constant temperature gradient and temperature difference inside the dryer and are of importance primarily for ensuring maximum heat utilization. For cocurrent operation the major portion of heat is transferred in the feed end of the dryer regardless of the air and material heat transfer capacities.

Comparison of the four cases enumerated indicates that cocurrent operation will in general ensure a desirable time-temperature profile at a higher dryer capacity than will countercurrent opera-

Table 5.—Observed and Calculated Hold-Up of Rotary Dryers for — 16- +20-mesh Ammonium Nitrate *

Test	Nitrate rate, lb./min.	Air rate, ft./sec.	Slope, ft./ft.	Rotation, rev./min.	Hold-up, lb./ft. Observed	Hold-up, lb./ft. Calculated	Retention time, min. Observed	Retention time, min. Calculated
1-ft.-diam. by 8-ft. countercurrent rotary dryer; 12 flights (Figure 6A)								
1	1.8	0	0.025	5.0	6.9	...	30	(See Fig. 7)†
2	2.0	0	0.025	5.0	6.9	...	28	(See Fig. 7)†
3	0.7	0.8	0.025	5.0	4.0	...	46	(See Fig. 7)†
4	1.5	0.8	0.025	5.0	6.9	...	37	(See Fig. 7)†
5	2.1	0.8	0.025	5.0	8.5	...	32	(See Fig. 7)†
6	2.25	0.8	0.025	5.0	8.5	...	30	(See Fig. 7)†
7	1.3	1.4	0.025	5.0	6.9	...	42	(See Fig. 7)†
8	0.8	2.2	0.025	5.0	6.7	...	66	(See Fig. 7)†
9	1.3	2.2	0.025	5.0	8.2	...	51	(See Fig. 7)†
10	2.2	2.2	0.025	5.0	9.1	...	33	(See Fig. 7)†
6-ft.-diam. by 35-ft. countercurrent rotary cooler; 12 flights (Figure 6C)								
3-7‡	550	3.0	0.067	4.8	152	142**	..	.....
3-8	550	3.0	0.067	4.8	152	142	..	.....
3-9	600	2.7	0.067	4.8	166	155	..	.....
3-10	700	3.1	0.067	4.8	176	180	..	.....
3-11	700	3.0	0.067	4.8	176	180	..	.....

* Bulk density—60 lb./cu.ft.
† Curves for calculated retention time shown in Figure 7.
‡ Tests 7-11 from Table 4.
** Calculated hold-up, $H/L = \frac{F}{2.6\ DR(\phi - 0.005v)}$.

tion. Although the profile for case I, countercurent, is good, the maximum air-inlet temperature must be limited to prevent overheating the product and the material rate must be held low, relative to the air rate, to maintain this type of profile. Both these limitations curtail the dryer capacity for case I, countercurrent, to a relatively low value compared with that for cocurrent operation, where these limitations do not apply. Cocurrent dryer operation has a further advantage over countercurrent operation in that the transport of the finer material, which dries relatively fast, is assisted rather than retarded by the air flow.

This simplified classification of cases becomes somewhat more involved in actual drying practice, where the latent heat of evaporation changes the apparent heat transfer capacity of the material in its progress through the dryer (*14*). For countercurrent operation therefore the feed end containing wet material may show a case III profile while the discharge end may have a case I profile. Where maximum dryness of the product is desired, countercurrent operation under case I condition at the discharge end may be advantageous provided that condensation for case III conditions at the feed end is avoided. In practice the choice of an appropriate time-temperature profile for dryer operation depends either on drying experience with the material involved or on tests designed to furnish this information (*7* and *13*).

Approximate air and material temperatures corresponding to the desired profile, together with the heat transfer requirement of the dryer, provide the information for calculating the required air rate, assuming a nominal allowance (5 to 50%) for heat losses, depending on the operating temperature and insulation used. The dryer diameter is sized according to the air volume to maintain a unit velocity or mass rate sufficiently low to avoid excessive dust loss. The maximum permissible air velocity for different materials varies widely and must be established on the basis of drying experience or tests. Mass air rates up to 1,200 lb./(sq.ft.)(hr.) were permissible for granulated ammonium nitrate used in these tests.

The dryer hold-up is derived directly from specifications on the desired time-temperature profile of the material. Based on the diameter determined above, the length is chosen to accommodate the required hold-up within limitations imposed by the flight design. The preferred flight capacity ranges from 8 to 15% of the internal dryer volume depending on specific characteristics of the material such as angle of repose, stickiness, or crust formation.

Adequate heat transfer capacity is next assured by choosing a speed which, together with the hold-up and flights discussed above, will ensure the desired cascade rate and heat transfer coefficient. The dryer slope is finally calculated to provide the required hold-up for the air rate and dryer speed already specified.

This basis of design aligns all major variables into a rational sequence that permits the design of a dryer for any specific application.

For rotary coolers only the terminal air and material temperatures are important; the actual internal profile may be of very little significance. Emphasis in cooler design therefore shifts more to heat transfer capacity and less to retention-time requirements. Moisture condensation not usually being a problem encountered in cooling, the relative advantages between cocurrent and countercurrent cooling are less important than for drying.

If the material to be dried is too wet or sticky to cascade freely, the requirements for efficient heat transfer and for continuous trouble-free dryer operation will not be met. For cases of this type, the dryer should be designed for recycling sufficient dry material or dried fines to condition the wet material to a freely cascading consistency.

The heat transfer coefficient for rotary dryers and coolers was found to be proportional to the material-cascade rate over a wide range of primary variables. The ratio of the heat transfer coefficient to the cascade rate for full flight loading varied most strongly with flight size and to a lesser extent with rate of rotation and the size and type of material. This ratio ranged from 0.7 B.t.u./(° F.)(cu.ft.) of material cascaded for the largest dryer tested to 2.2 B.t.u./(° F.) (cu.ft.) for a 1-ft.-diam. experimental unit. This factor was found to be relatively insensitive to changes in plant dryers and therefore serves as a basis of dryer scale-up by analogy with the same factor derived from similar or related drying operations.

The material transport rate through dryers was found to follow a characteristic distribution function which was confirmed by experimental observations. Dryer hold-up was shown to follow the relation

$$H = \frac{FL}{f(H)DR(\phi - mv)}$$

where $f(H)$ is a function of hold-up varying from 2 to π for a range of lightly to fully loaded dryers.

Acknowledgment

Permission for the use of data obtained from the Department of Chemical Engineering of the Tennessee Valley Authority is gratefully acknowledged.

Notation

(Applicable to any set of consistent units; volumetric and weight units shown.)

- A = flight load, cu.ft./ft. or lb./ft.
- C = cascade rate, cu.ft./ft. or lb./ft.
- D = dryer diameter, ft.
- F = feed rate, cu.ft./min. or lb./min.
- G = mass air rate, lb./(sq.ft.)(hr.)
- H = hold-up, cu.ft. or lb.
- i = numerical index
- k = constant
- L = length of dryer, ft.
- M = radial flight depth, ft.
- m = constant
- N = number of flights
- n = constant
- Q = quantity of heat, B.t.u.
- R = rate of rotation, rev./min.
- S = length of trajectory, ft.
- T = temperature, ° F.
- t = time, min. or hr.
- V = material transport velocity, ft./min.
- v = air velocity, ft./sec.
- W = differential flight load, cu.ft./ft. or lb./ft.
- X = distance, ft.
- θ = angle of repose
- ϕ = dryer slope

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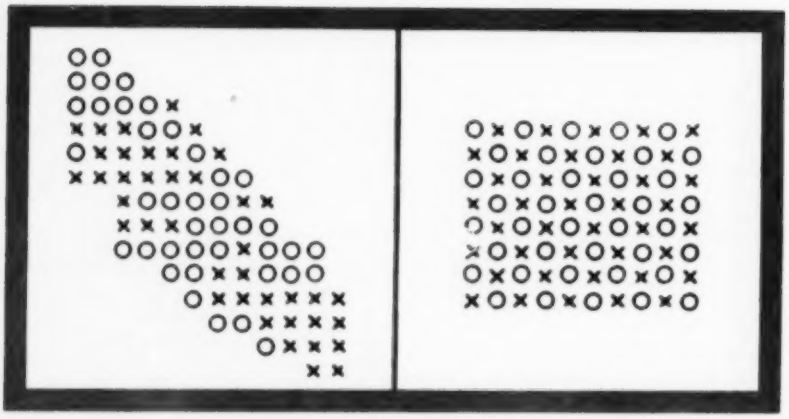
Presented at A.I.Ch.E. Forty-sixth Annual Meeting, St. Louis, Mo.

The illustration of Type H dryer installation on page 467 was supplied by the General American Transportation Co.

dry mixing of solids

Lincoln T. Work

Consulting Engineer, New York



Perry's handbook—courtesy McGraw-Hill Book Co.

Unmixed
Two Materials Showing
Uneven Particle Distribution

Mixed
Two Materials Showing
Even Particle Distribution

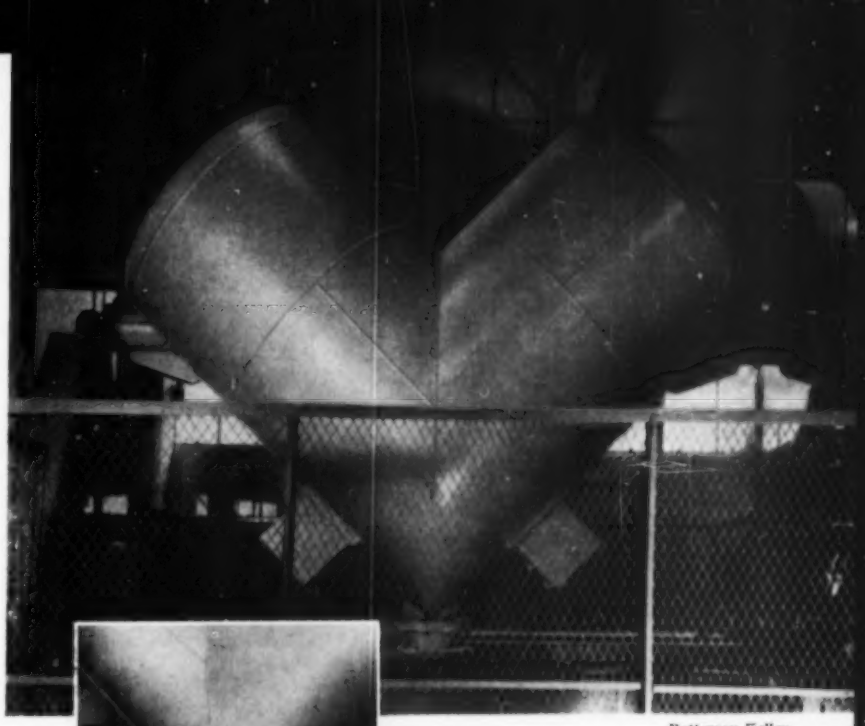
Fig. 1. The effect of mixing.

Although it is an old art, dry mixing was given scant treatment in chemical engineering texts of even as short a time back as the late thirties. It was not a science which warranted status as a unit operation. Much has been done to understand the mixing of solids, but it is still largely an art. Furthermore, the nature of particulate solids is such that, though mixing is achieved, there may subsequently be segregation. For this and for economic reasons, mixing is often largely effected through uniform feeding of materials into a flowing stream, depending upon the movements within the stream to attain a suitable degree of homogeneity. Thus, there is mixing equipment, and mixing is also obtained in other equipment. After a mixture is made, further steps are often needed to avoid segregation. The manner of filling a hopper and the means for discharging it, transportation in bulk or in a package, and even the conveying system employed in a plant can undo the work of making a mixture. The problem ought to be viewed as an overall part of the process, rather than as a unit operation.

Requirements

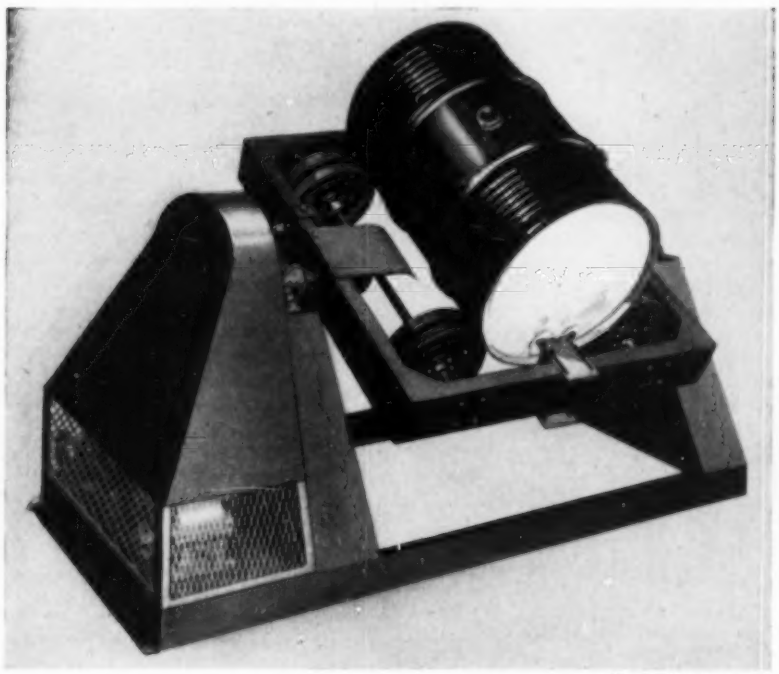
For any one mixing problem there is a minimum requirement; and it is generally desirable to exceed this to insure that the minimum is always met. Inherently, the requirement is associated with product quality. A packaged mixture of dehydrated vegetables for making soup may only require that each package contain similar amounts of each ingredient, according to a formula, so that, when the package is made into a batch of soup, the resulting product will be identical with that from another package. The problem could be solved by premixing to insure this goal or by feeding measured quantities of each component into each package. From this type of mixture to the most intimate one, there are many degrees of requirements. As an example of one of the more exacting requirements, there is the case of face powder. White and colored particulate solids and perhaps small amounts of perfumes, waxes, and medicaments must be blended intimately so that each part of the thin layer applied shall be uniform, that there will be no streakiness from different colors or texturing materials, and that the pigmentary color be fully and completely developed.

Nor is it to be considered that there is no mixing problem when a material is of one composition. If it varies in particle size, the uniform distribution of the different particles may require



Patterson-Kelley

Fig. 3. V-mixer.



U. S. Stoneware Co.

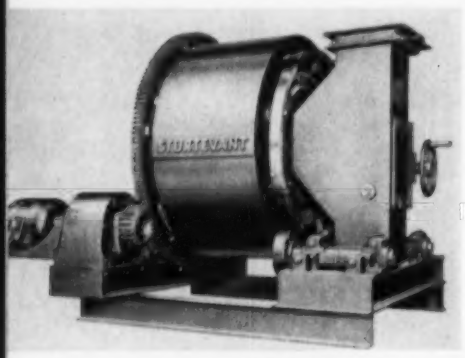
Fig. 2. Rocker roll drum.

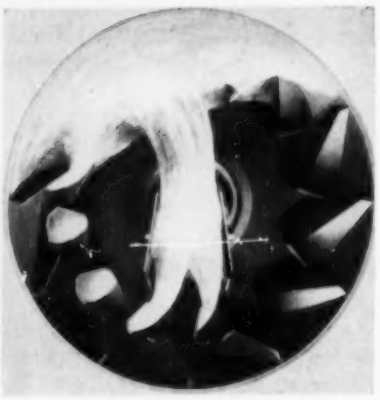
mixing. The field of powder metallurgy affords an example. Even though the powder is to be press molded as delivered, it is good practice to mix an entire drum before withdrawing material for use. The relation of size distribution to packing volume is such that only by a procedure of this kind is it assured that each piece receives a similar amount and quality of powder to insure uniform character of the pressed parts. The mixing step at the point of use is a corrective for segregation in transit. Many other examples could be cited, but these adequately show that there is a required quality to a mixture which must be defined.

A statistical treatment of mixing will help to get the concept. The two figures of black and white dots representing different particles show the relation between a low-grade mixture and a good one (Figure 1). How then, is one to tell if this applies to his product in the proper degree? An over-all analysis of a properly quartered sample is of no value. In fact the sampling process tends to insure mixing. The uniformity of spot samples of an appropriate size may measure the quality of mixing; but, at times, even the smallest measurable sample is inadequate. Reliance upon a

uniformity check of the final product, as to its variation in use, is helpful, since it is likely to be the same criterion the user employs in making a complaint.

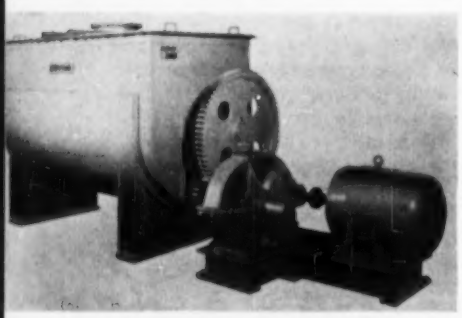
Several factors have an important bearing in meeting these requirements.





Sturtevant Mill Co.

Fig. 4. Cylinder with vanes.



J. P. Devine Co.

Fig. 5. Double-ribbon mixer.

1. **There is a big difference between mixing together equal quantities and mixing a small percentage, as with the vitamins in flour. There may be merit in multistage mixing when small amounts must be well mixed with the base material, whereby a rich master mix is made, and then itself measured into more of the major component and further mixed. Otherwise, thorough mixing may secure the desired result.**
2. **Density of the components in a mixture is important not only in mixing but also as bearing on segregation. Where feasible, heavy material is put on top of light material to avoid pocketing the heavy material in the base of the mixer.**
3. **Particle size is important since wide differences in size may create mixing and segregation problems. A dry 20- to 50-mesh sand, containing a small percentage of clay, may give after shipment a uniformly clean sand except for a small amount of clay-sand mixture at the bottom. In this case the fines settle to fill the voids in a small portion of the material. In another case, the mere piling of material may cause the coarse particles to move preferentially to the outer edges of the pile, leaving less coarse material mixed with fines in the core.**
4. **Particle shape is a factor. Flat, slippery particles and spheres, being mobile, may segregate. Fibrous material may not be broken apart easily to disperse it with the other components of the mixture. Mixing and handling need to have these factors taken into account.**

Mixing Action

As has been shown in Figure 1, the unmixed or partially mixed state shows groups of similar particles together, while the dissimilar particles are also grouped. Minimum areas in the "unmixed" figures do not consistently show the same ratio of crosses to circles as is to be found in the "mixed" figure. This is the task for mixing and blending. It is like the shuffling of a new deck of cards. Proficient splitting expedites the process; adequate shuffling requires a great many such actions. Merely to remove some cards from one end of the pile and place them at the other end will not achieve mixing.

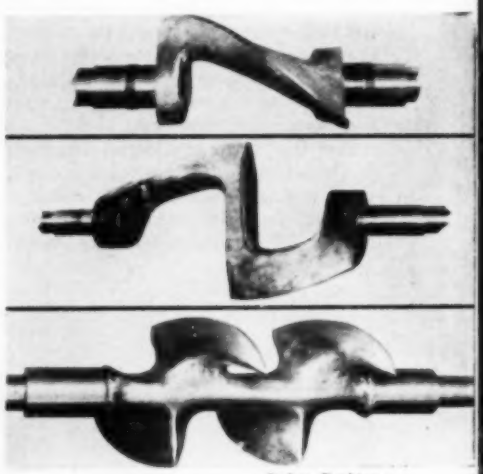
Means for mixing may be classified grossly, and the details may be developed for individual mechanisms.

Mixers

1. BATCH MIXERS (Figures 2-7)

For this operation the component materials are weighed out in their proper amounts and placed together in the mixing chamber. This may be a drum which is closed and rolled around its axis, turned end over end, or subjected to a combination of these actions. A V-type drum mixer is a variation of this. In the order in which these have been named, there are increasingly better turbulence and breaking apart of the material to increase the speed of the mixing operation. In lieu of a drum revolving on its axis, a larger device is a ball mill. Used empty or with a limited number of balls—possibly rubber balls—mixing action is achieved. This may be further improved with curved blades on the inside of the liner to cause side motion as well as tumbling motion. Rotating the drum end over end has a somewhat better counterpart in the double cone mixer, which is in effect a drum with tapered ends. The conical ends cause lateral as well as tumbling motion to expedite the mixing. A variant of these devices is the tilted bowl mixer.

In other cases the casing is static and the interior of the chamber contains some type of stirring device. This may be of the lighter type with a ribbon



Baker Perkins

Fig. 6. Kneader mixer blades.

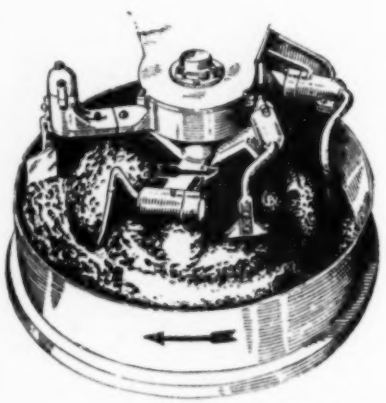


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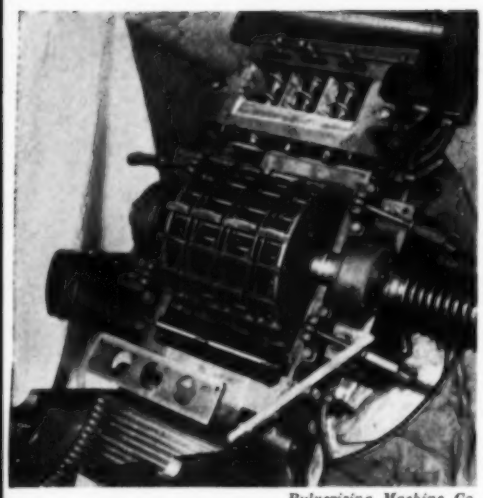
Fig. 7. Rotating pan mixer.



Pulverizing Machine Co.

Fig. 8. Hammer mill.

spiral or a double-reverse-ribbon spiral or it may be of the heavier type with kneader blades. These devices apply a rubbing action that is useful when one or more of the components tends to be lumpy. Vigorous action in breaking down lumps may be obtained in the rotating pan mixer.

2. CONTINUOUS MIXERS (Figures 4, 5, 6, 8, and 9)

Some structures used for batch mixing can be carried over to continuous mixing and there are new structures more suitable for continuous operation. In general, a premise for continuous mixing is that there shall be a rough premixing, whereby unit volumes, which are small in relation to the operating volume of the mixer, are each of the proper composition. Revolving tube mixers—with or without balls or liner strips, ribbon mixer, and a positively driven centrifugal-type bowl mixer—comprise batch types which are employed also for continuous operation. In addition, grinding mills find effective use for mixing. These may be of the roller type, but more frequently they are of the hammer- and jet-mill classes. Such mills disperse material quite fully so that, when the freely moving particles are collected as a powder mass, they are well mixed.

It is good practice to employ the step of transportation as a means of mixing. The streams of solid to be mixed are fed uniformly from weighing belts at the storage hoppers and fall together on a crossbelt. Then a vibrating feeder, a screw conveyor, or an air pumping system in a pipe can serve to give varying degrees of mixing, increasing in the order named. Even dropping two powder streams through baffle or screen spreaders into a hopper can be made to achieve mixing.

3. SYSTEM MIXING

Instead of having a device set apart for mixing, it is usually desirable to attempt mixing at appropriate steps in the process. A good example of that is in the manufacture of portland cement. Limestone and clay-bearing rock of uneven composition need to be ground and blended to a close relationship between several chemical components so that the burning reactions are uniformly correct. Cars from the lime-rich and the silica-rich section of the quarry are made into a train in the ratio expected to give the proper composition. Then, at the first breaker mill, these cars are dumped in rotation so that some degree of mixing is attained. Further mixing takes place during subsequent grindings and during storage and removal from storage. If, before the final grinding, there is still a small difference in composition from that desired, streams may be blended together and fed to the tube mills with assurance that full correction has been made.

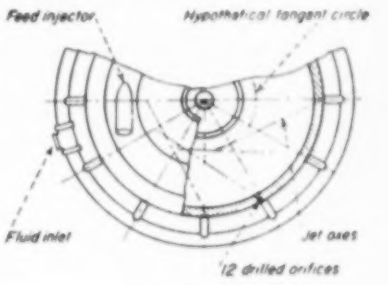
One of the advantages of system mixing, besides the saving of a step, is the fact that consideration is also given to segregation. If powder is dropped into a hopper at one point so that it piles up, coarse or heavy components slide further than do fine and lighter ones. Withdrawal is not uniform and the segregation which has been created will remain. Likewise, when powders are transported in pipes suspended in air, coarse and heavy particles tend to be in the lower portion of pipe, or at the outer periphery of a bend. Streams, split when segregation exists, may give substantially different mixtures in the parts. To insure homogeneity in bins, it is well to spread the material by baffles or screens so that it feeds flat. In removal, vibrators or other devices will help. The separation of powder-bearing air streams calls for a good mixing pattern and symmetrical withdrawal of the streams in such a way that these adverse factors are corrected.

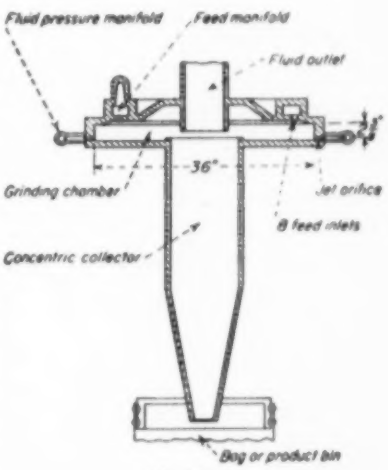
One method of system mixing, also employed for batch operation, is to segregate material, as by sieving, into portions which have little tendency to segregate, and to carry each portion through appropriate steps until it is ready for final proportioning and mixing.

A variety of aids in mixing may be employed, of which a few may be mentioned. It is sometimes wise to dry the material thoroughly before mixing so that agglomerates will be broken up. Another approach which minimizes segregation is to aggregate material after mixing. Use of a ball or roller mill to compact the individual particles into larger ones, each of which contains the mixture, achieves this. Addition of a little moisture or, if permissible, a little binder is another means to effect this result.

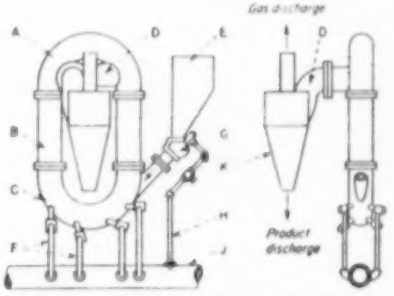
4. MIXING DEVICES

The accompanying illustrations show some types of devices which are employed for mixing. The problems, in their selection and use, are too diverse to give any formula for choice or to set up costs. These are matters for a specific problem.





Micronizer.



Perry—McGraw-Hill Co.

Reductionizer.

Fig. 9.

- **A** Top tube turn
- **B** Straight section of grinding tube
- **C** Bottom tube turn
- **D** Product outlet
- **E** Solids feed funnel
- **F** Fluid nozzles
- **G** Venturi-type feed injector
- **H** Fluid line to feed injector
- **J** Fluid pressure manifold
- **K** Cyclone collector

ABSTRACTS

*Abstracts of papers published in "Collected Research Papers for Spring, 1954," Chemical Engineering Progress Symposium Series No. 10, Vol. 50 (1954). The volume may be purchased from Chemical Engineering Progress, 25 West 45 Street, New York 36, New York.**

Cocurrent Turbulent-Turbulent Flow of Air and Water-clay Suspensions in Horizontal Pipes

Henderson C. Ward and J. M. Dallavalle
Georgia Institute of Technology

With air used as the gas phase and four concentrations of kaolin clay in water used as the non-Newtonian materials, two of the suspensions behaved as pseudoplastics and two exhibited Bingham-plastic properties. Suspension flow rates were varied from 0.15 to 16 lb./sec. and air-flow rates from 0.0015 to 0.025 lb./sec. The pressure-drop data obtained on the cocurrent flow of air and these suspensions in the turbulent-turbulent region correlated within the range of ±20% by the ϕ-X method of Lockhart and Martinelli, and in the turbulent-flow region the usual Newtonian-friction-factor-Reynolds-number relationship was found to be valid.

Chemical Engineering Progress Symposium Series, **50**, No. 10, 1 (1954).

Mass Transfer Between Two Liquid Phases

K. F. Gordon and T. K. Sherwood
Massachusetts Institute of Technology

This study was designed to test the applicability of the concept of additivity of resistances for interphase transfer of solute between two liquids by measuring mass transfer rates for a variety of solutes passing from one to another of two immiscible liquids.

Chemical Engineering Progress Symposium Series, **50**, No. 10, 15 (1954).

Separation of Azeotropes by Diffusion Through Porous Membranes

Donald H. Hagerbaumer and Karl Kammermeyer
State University of Iowa

Study of eleven minimum-boiling-point azeotropic systems: (1) acetone methanol, (2) carbon tetrachloride ethyl acetate, (3) cyclohexane ethanol, (4) benzene isopropanol, (5) benzene *n*-propanol, (6) benzene cyclohexane, (7) benzene methanol, (8) benzene ethanol, (9) acetone carbon disulfide, (10) isopropanol water, and (11) ethanol water, revealed that binary azeotropes can be separated by using porous glass as a membrane. All the systems except benzene cyclohexane generally separated in favor of the component possessing the lower critical pressure.

Chemical Engineering Progress Symposium Series, **50**, No. 10, 25 (1954).

Lateral Diffusion in Gases Flowing Through Tubular Reactors

H. E. Hoelscher
The Johns Hopkins University

The equation for diffusion of a single species through an inert gas was solved for the case of gas flowing through a tubular reactor with a depletion process occurring at the wall. Concentration profiles were calculated for various operating conditions and depletion rates. Under only relatively few sets of operating conditions is the concentration profile sufficiently flat to permit use of the average bulk-gas concentration as the concentration existing at the tube wall.

Chemical Engineering Progress Symposium Series, **50**, No. 10, 45 (1954).

Flow Through Irrigated Dumped Packings: Pressure Drop, Loading, Flooding

Max Leva
Consulting Engineer

In order to estimate the pressure drop in the loading-flooding zone, for which empirical equations will give low results, a generalized isobaric plot was prepared on the basis of the pressure-drop measurements of Lubin observed in a 24-in.-diam. tower. The graphical presentation includes most of the loading data in the literature.

Chemical Engineering Progress Symposium Series, **50**, No. 10, 51 (1954).

Effect of Total Pressure on the Gas-Film Absorption Coefficient in a Packed Tower

Walter Zabban and Barnett F. Dodge
Yale University

The effect of total pressure on the gas-film absorption coefficient has been studied by varying the pressure over the range of 1 to 14 atm. In the systems investigated air was used as a carrier gas with either acetone or methanol vapor as solutes. The solutes were absorbed by water flowing countercurrently to the gas in two packed towers, 6 and 12 in. in diam. Gas-film absorption coefficients were calculated from the experimental values of the over-all absorption coefficients by using the well-known equation for additive film resistances and the calculated values of liquid-film coefficients obtained from the Sherwood and Holloway correlation.

Chemical Engineering Progress Symposium Series, **50**, No. 10, 61 (1954).

Mass Transfer Between Immiscible Liquids in Continuous Flow in an Agitated Chamber

Andrew E. Karr and Edward G. Scheibel
Polytechnic Institute of Brooklyn

The investigation was undertaken to attempt to correlate the important variables affecting mass transfer between immiscible liquids in continuous flow in an agitated chamber. Mass-transfer rates in a single mixing section were determined by eliminating countercurrent flow in the packed sections of specially constructed columns. Over-all mass-transfer coefficients for three different systems were correlated by employing activity as the driving force. Equations for predicting stage efficiencies in agitated chambers dimensionally similar to those employed in the work were developed and can be applied to the design of multistage liquid-liquid-extraction columns.

Chemical Engineering Progress Symposium Series, **50**, No. 10, 73 (1954).

Transfer of Momentum in Jet of Air Issuing Into a Tube

L. G. Alexander, E. W. Comings, H. L. Grimmett, and E. A. White
University of Illinois

The results of experiments in which a jet of air issued into a duct and mixed with air entrained from the room are reported. The mathematical treatment proposed by Alexander was used to interpret and correlate the results for the special case of the jet in the plane of the duct entrance, in this case the initial boundary conditions permitting a solution of the equations of motion.

The transport of heat and mass is similar to that of momentum, and it is to be expected that measurements with a heated jet or with a jet of one gas discharging into a dissimilar gas can be correlated by the same methods.

Chemical Engineering Progress Symposium Series, **50**, No. 10, 93 (1954).

Mass-Transfer Effects and Variable Productive Area in Fixed-Bed Catalytic Converters: Hydrogenation of Propylene over Palladized Alumina.

R. F. Kayser and H. E. Hoelscher
The Johns Hopkins University

The kinetics of the hydrogenation of propylene over a palladized alumina catalyst were studied as a function of temperature, composition, and flow rate through the catalyst bed. The rate was found to vary markedly with flow rate. Mass transfer through the fluid film surrounding the catalyst particles controlled the rate of production, and in addition the extent of the available active area in the catalyst bed varied with flow rate.

Chemical Engineering Progress Symposium Series, **50**, No. 10, 109 (1954).

* See advertisement on page 72.

The rest of the papers will be abstracted in a later issue.

Pumps

recent communications of interest from the manufacturers

COMBINATION LOW HEAD PUMP AND MIXER

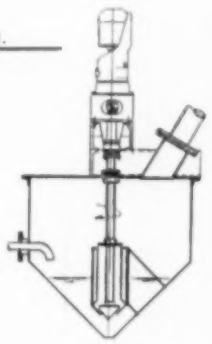
A current gas absorption problem presented to us involves the closed-circuit recirculation of the absorbing liquid into a continuous gas stream. Since the entire system is under 300 lbs. pressure, it was considered desirable to eliminate outside pump recirculation.

The design developed for this service is a variation of the Turbo Saturator (patented) shown in Figure 1. The lift impeller at the bottom of the draft tube acts as a low head pump, raising a head of liquid through the orifice in the bottom of the draft tube to overflow the top brim. At this point, a second impeller picks up the overflowing stream and sprays it into the gas atmosphere. The sprayed liquid falls back into the reservoir surrounding the bottom of the draft tube and is recirculated.

The head development by the centrifugal type impeller is achieved by closing off the top side of the impeller. It rotates at close clearance to the draft tube bottom, having an orifice smaller than the impeller diameter. Stator blades or baffles are installed around the impeller periphery to eliminate swirl and force the impeller to pump centrifugally.

Another recent installation required the development of a circulating head

Fig. 1.



(Continued on page 72)

PUMP FEATURES ELEVATED STUFFING BOX

In the plant of a large Ohio Valley chemical company, the operators were confronted with the serious problem of stuffing box losses in horizontal shaft pumps transferring concentrated sulfuric acid, saturated with chlorine, from a reactor. This chemical mixture is not a particularly formidable one insofar as its corrosive effect on materials of construction are concerned, as Hastelloy stands up very well against it. However, the liquid lost out of the stuffing box absorbed moisture from the air, and a serious corrosion problem developed.

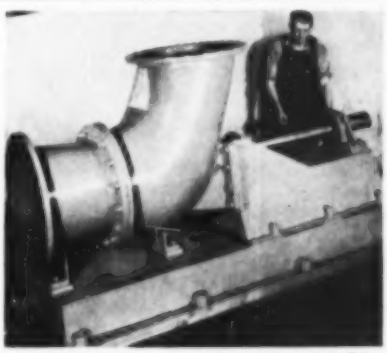
The operators tried various designs of pumps and stuffing boxes and while this improved conditions somewhat it was felt by our engineers that there was no effective immersed seal which could be expected to operate over an important period of time without incurring the expense of frequent maintenance attention.

Based on other similar experience, it was suggested by our engineers that vertical shaft pumps be installed in receiving tanks alongside the reactor, positioned so that the liquid level would

(Continued on page 70)

AXIAL PUMP HANDLES ACID SOLUTION

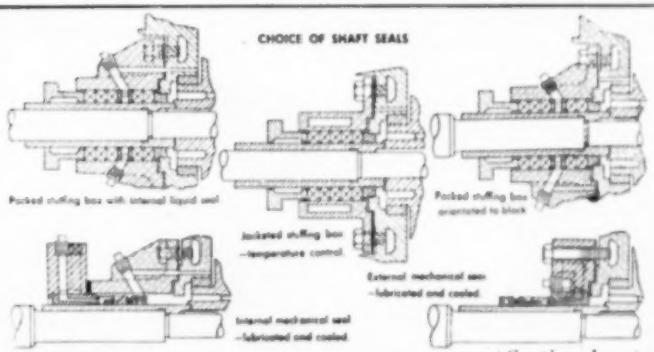
The pump shown in the accompanying photograph is being used for the handling of weak sulfuric acid solution containing some dissolved sulfates. It was selected primarily through its ability to deliver a large volume of flow against a low head. This particular pump is rated at 10,000 gal./min. against a 10-ft. head. The propeller rotates at 700 rev./min. and is driven by a 40 h.p. motor through a V-belt drive with adjustable pitch pullies which permit adjustment of the speed to actual operating requirements. To avoid using internal bearings, guide vanes are installed ahead of the propeller. The pump is noteworthy in our estimation because of its size, simplicity and its efficiency, which is estimated to be 83%. Frequently such pumps have not in the past been able to achieve such a level of efficiency. Ma-



(Continued on page 70)

CHEMICAL PUMP FEATURES INTERCHANGEABILITY

A new series of 1750 r.p.m. centrifugal pumps for corrosion service offer an unusually wide selection of components, enabling the designer, plant operator or maintenance engineer to achieve many advantages. Among these are the ability to easily and at low cost change the assembly of features to accommodate other operating conditions than those for which the pump was originally intended. Another is reduction in number of spare


CHOICE OF SHAFT SEALS
Packed stuffing box with internal liquid seal
Packed stuffing box oriented to block
Jacketed stuffing box —temperature control
External mechanical seal —lubricated and cooled
Internal mechanical seal —lubricated and cooled

(Continued on page 71)

A Chemical Engineer in Spain

B. F. Dodge

Late in January, 1953, my phone rang and a voice speaking from the State Department in Washington said, "Will you go to Spain by February 1 or at the latest, March 1, and deliver some lectures on chemical engineering?" It sounded intriguing, but there was a catch to it—the lectures had to be given in Spanish!

I wanted very much to see Spain and I felt that "spreading the gospel" of chemical engineering—for it is largely an American development, not very widely accepted in Europe—was a worth-while objective. Finally, after much debate, I agreed to lecture for a two-months' period beginning on January 15, 1954.

Learning Spanish in a Hurry

That summer I devoted most of my spare time to learning Spanish and writing my prospective lectures. I soon realized that the situation was quite different from that which I faced in France, when I had given a course in chemical engineering thermodynamics to a small group of advanced students. In that case I was throughly familiar with the subject matter, sufficiently proficient with the language that I could outline in French the material for each class meeting, and could fill in extemporaneously from the outline.

By correspondence with Professor Calvet, professor of technical chemistry at the University of Barcelona where the lectures were to be given, I learned that the audience might be anywhere from sixty to one hundred persons, some of whom were students of chemistry at the University and the rest made up of University faculty and practicing chemists and engineers from industries in and around Barcelona. Furthermore, it was apparent that the subject matter should range rather widely over the field of chemical engineering with emphasis perhaps on separation operations such as distillation, absorption, and extraction. I was not immediately prepared to give lectures in this field even in English, let alone in a foreign language. There seemed to be no alternative but to write out each lecture in detail in English, then translate it into Spanish, and finally to read it. I prepared for what I thought would be about sixteen lectures, but actually there was enough material for three lectures a week for a period of eight weeks.

Since lectures to so large a group would not simulate the informal type of class meeting to which I was accustomed, it soon became evident that the talks should be delivered in idiomatic Spanish, which I could never achieve in the limited time available. The first few lectures I arranged to have translated by Spanish people living in New Haven, but the result was not altogether satisfactory; it was a slow process and could never be completed on time. I finally explained my difficulties to Professor Calvet, whose suggestion to send all the English versions to Barcelona for translation by one of his younger colleagues who could read but not speak English solved this most serious problem.

I can testify from my experience with both Spanish and French that there is only one way to learn to speak a language and that is to converse in it on every possible occasion. Reading is of little use without practice in speaking. Listening to records is valuable ear training but is completely useless as far as learning to speak is concerned.

In order to gain experience both in speaking and understanding Spanish before called upon to lecture, we managed to arrive in Spain a little more than two weeks ahead of the work schedule.

I will never forget my first meeting with Professor Calvet after our arrival in Barcelona. I had sent him a telegram from the border in my best Spanish and I had prepared in my own mind many questions to ask him in Spanish. What was my surprise to learn that he spoke very good English—far better than my Spanish!

Barnett F. Dodge is Vice-President of the Institute, and is professor and head of the department of chemical engineering at Yale.

Hospitality a la Barcelona

I hasten to add that the Calvets were an exception. Few of the others with whom we came in contact could either speak or understand English and I became convinced of the need to give my lectures in Spanish. It was a great relief to know that there was someone to whom I could turn when questions in Spanish proved too much for me. The poor Calvets! Whenever we were invited out for a social evening, they were invariably included in the party so that they could come to the rescue when the conversation bogged down. I might say at this point that my wife and I found the Spanish to be very hospitable people; we were invited to the homes of the faculty on a number of occasions and parties in our honor were also given at some of the local restaurants.

Motoring through Spain

Just two weeks before the lectures got under way, we started out on our motor tour rather late on New Year's day (We had celebrated the coming of the New Year at the home of the American Vice Consul in charge of cultural affairs). This was to be a hurried 12-day circular trip. In Paris we had bought a used English car because experience had taught us that traveling by auto is by far the best and most convenient way to see a country and get to know its people. We packed a lot of sight-seeing into those few days!

The first lecture, a general one on the profession of chemical engineering, had been publicized by the University through the local press as the first American professor to go to Spain under the new State Department policy.

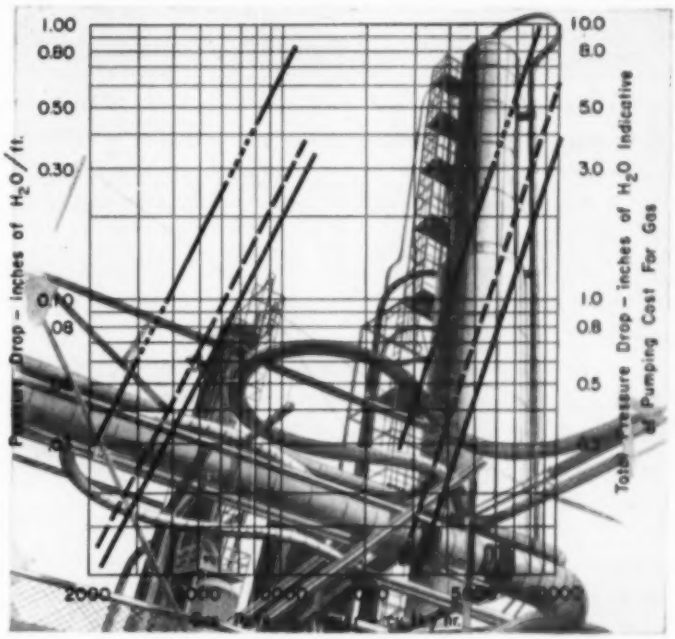
(*Continued on page 62*)

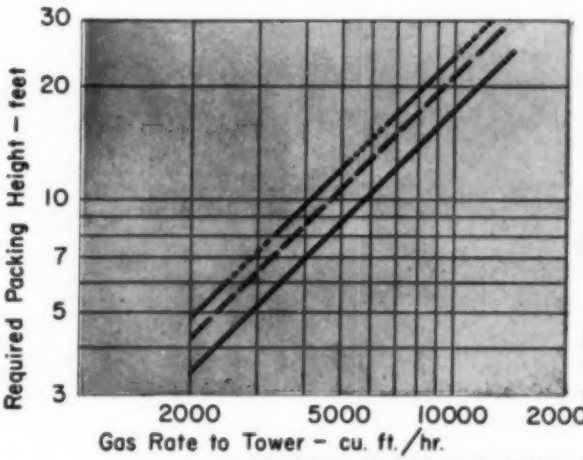
HOW INTALOX SADDLES CAN REDUCE TOWER HEIGHT AS MUCH AS 30%

If your choice of a tower filling is based on what packing will, for an equivalent through put, be most economical in both initial tower investment and operating costs — take a look at these charts and their accompanying table.

This is another typical demonstration of the striking savings that can be made through the use of Intalox saddles. It is based on observed capacity data in a pilot plant operation where CO_2 is removed from an inert atmosphere using a dilute aqueous caustic solution.

It will pay you to analyze tower construction and operating costs in the light of greatly reduced tower height and weight. You'll quickly see why cost-conscious engineers are more and more frequently designing towers to use to the full pronounced advantages of Intalox saddles.





1" RASCHIG RINGS
1" BERL SADDLES
1" INTALOX SADDLES

Chart No. 1 (Above)

Pressure drop data comparison. Data shown both in inches of H_2O per foot, and total pressure drop in inches of H_2O.

Chart No. 2 (Left)

Showing comparison of packed height required for removal of CO_2 from an inert atmosphere using dilute caustic liquor as the scrubbing liquid.

COMPARATIVE STUDY BASED ON DATA SHOWN ABOVE

	Tower Crossection, Sq. Ft.	Required Packed Height* Ft.	Packing Weight Lbs.	Weight of Steel Shell—⅛" Thick	Weight Packing & Shell Lbs.	Total Column Hold-up Cu. Ft.	Pressure Drop— Inches of H_2O**
1" Raschig Rings	1.0	12.0	480	672	1152	0.76	2.0
1" Berl Saddles	1.0	10.5	473	588	1061	0.68	0.77
1" Intalox Saddles	1.0	8.6	293	482	775	0.68	0.47

* To remove 90% of the CO_2 from the gas; initial gas composition being the same in all cases.
** For a gas flow of 5,000 cu. ft./hr. and essentially atmospheric operation.

UNITED STATES STONEWARE CO.
Process Equipment Division AKRON 9, OHIO
NEW YORK CHICAGO HOUSTON

This Scrubber handles Hydrochloric Acid and Chlorinated Solvents at High Temperatures

..... Materials and Construction by EL CHEM

• The Tail Gas Scrubber shown at right is one of EL CHEM's recent installations in the chemical processing industries. This type of construction, planned, engineered and installed by EL CHEM, is used in plants producing organic chemicals.

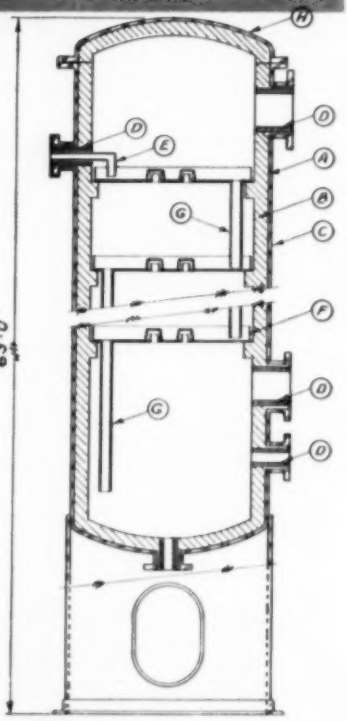
• It resists acids, *all alkalis* and most organic liquids. It features also high heat resistance.

• *All materials of construction* (listed below sketch) *are manufactured by* EL CHEM. Among them is LECITE, a recent development in Furfuryl Alcohol resin cement.

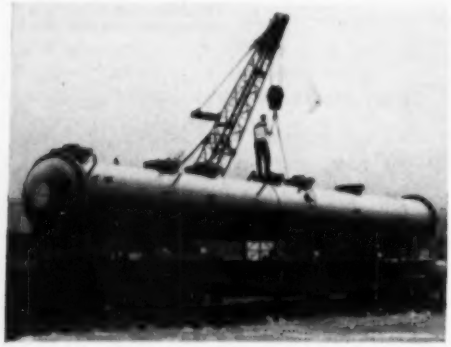
• As a corrosion-proof bonding agent, LECITE combines the desirable properties of the phenolics, without their drawbacks. It serves also as an impervious liner, when reinforced with glass cloth or metal mesh, as mortar for corrosion-proof brick lining and as an impervious membrane between brick or tile floor and the concrete sub-base.

• LECITE is used in the construction of acid-proof floors, chemical process equipment, such as scrubbers, reactors, storage tanks, filters, alkylators, neutralizing tanks, stacks and fume ducts.

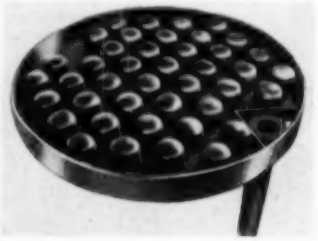
• LECITE has been used successfully for many years in plants producing chemicals, dyes, Viscose, nylon, textiles, synthetic resins, petroleum products, steel, copper and many others.



(a) EL CHEM combination membrane
(b) One layer acid-proof brick, joined with LECITE acid-, alkali- and solvent-proof resin cement
(c) Welded steel shell
(d) Porcelain sleeve
(e) DURO-WARE inlet pipe
(f) DURO-WARE bubble cap tray (see picture at left)
(g) DURO-WARE downcomer
(h) Brick-lined removable dished head



Assembled at our Emmaus plant, shipped out by rail and installed by us at destination.



DURO-WARE bubble cap tray (f) in drawing at right.

EL CHEM renders a complete, all-inclusive service: materials, plans, engineering and installation. Our engineers will survey your corrosion problem, make recommendations and prepare plans and estimates — without obligation. At your command here is the benefit of more than four decades of experience in solving about every kind of problem in industrial corrosion. *Write for technical literature.*

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742 Broad Street, Emmaus, Pa.

Manufacturers of Acid- and Alkali-proof Cements, Linings and Coatings since 1912

Representatives:	Phone:						
Atlanta, Ga.	Ekhaven	8311	Detroit, Mich.	TRinity	5-7026	Niagara Falls, N.Y.	3757
Baltimore, Md.	Plaza	3326	Houston, Texas	Blackstone	3060	Phila., Pa. Tremont	W Ludlow 5-9061
Birmingham, Ala.		6-7667	Kansas City, Mo.	Diesel	2331	Pittsburgh, Pa.	Atlantic 1-1960
Cincinnati, Ohio	PArkway	6182	Knoxville, Tenn.		4-0617	Plainfield, N. J.	Plainfield 4-0768
Cranford, N. J.	Cranford	6-4018	Los Angeles, Calif.	SYcamore	3-2611	St. Louis, Mo.	WOodlawn 1-4317
			San Francisco, Calif.	Hillcrest	5-1936		

CAST HEAT ALLOY REFERENCE SHEET

N. S. MOTT, Chief Chemist and Metallurgist

The Cooper Alloy Foundry Co., Hillside, N. J.

Alloy: Heat Resistant 12% Chromium 60% Nickel Alloy.

Designations: A.C.I. HW; A.S.T.M. A297-49T Grade H.W.; S.A.E. No. 70334.

Chemical Aanlysis: C 0.35-0.75%; Cr 10-14%; Ni 58-62%; Si < 2.5%.

Applications: Premium alloy for carburization and cyclic heating services. Used for heat-treating boxes; cyanide and lead pots; retorts; hearth plates; muffles; enameling furnace supports; burner parts.

Machinability: Machines fairly well.

Heat Treatment: Used in "as-cast" condition.

Weldability: May be welded using a type 334 rod. No heat treatment is necessary after welding.

TYPICAL MECHANICAL AND PHYSICAL PROPERTIES

	Room Temperature		1400° F.	1600° F.	1800° F.
	As Cast	Aged *			
Tensile Strength, 1,000 lb./sq.in.	68	84	32	19	10
Yield Point, 1,000 lb./sq.in.	36	55	23	15	8
Elongation, %	8	6		21	40
Reduction in Area, %	7	7		15	50
Brinell Hardness	185	208	85	53	33

* 24 hr. @ 1400° F. furnace cooled.

Charpy Impact (Std. Keyhole ft.-lb.)	5		
Mod. of Elasticity (X10⁶ lb./sq.in.)	25		
Density (lb./cu.in.)	0.294		
Melting Point (° F.)	2350		
Specific Heat (B.t.u./(lb.)(° F.)) @ 70° F.	0.11		
Thermal Expansion (x 10⁶ in. (in.) (° F.)) ° F.	70-1000	7.9	
	70-1500	8.5	
	70-2000	9.2	
Thermal Conductivity (B.t.u./(hr.) (sq.ft.)(° F/ft.)) ° F.	70-212	7.7	70-1500
	70-1000		70-2000
Electrical Resistance (microhms/cu.cm.) @ 70° F.	108		

HIGH TEMPERATURE STRENGTH: (lb./sq.in.)	1400° F.	1600° F.	1800° F.
Stress Rupture (100 hr.)	10,000	5,900	3,300
Stress Rupture (1000 hr.)	7,700	4,500	2,600
Creep (1% 10,000 hr.)	6,000	3,600	2,000

MAX. (° F.) TEMPERATURE FOR CORROSION RESISTANCE:

Air Oxidation Resistance	1950
Oxidizing Sulfur Bearing Flue Gas (Low Sulfur)	1950
Oxidizing Sulfur Bearing Flue Gas (High Sulfur)	1700
Reducing Sulfur Bearing Flue Gas (Low Sulfur)	1950
Reducing Sulfur Bearing Flue Gas (High Sulfur)	1600

High Temperature Corrosion Resistance:

Molten Drawing and Tempering Salts ..... Excellent
Molten Cyaniding Salts ..... Excellent
Molten Neutral Salts ..... Poor
Molten High Speed Salts ..... None
Molten Metal Resistance ..... Excellent resistance to molten lead and good resistance to tin. Poor resistance to molten Babbitt and no resistance to aluminum or magnesium.

Carburization Resistance:

Pack Carburizing ..... Excellent
Gas Carburizing (< 15% CH_4) Excellent
Carburizing in Natural Gas (High CH_4) ..... Good

General High Temperature Characteristics:

This alloy has the best resistance to thermal fatigue cracking and to the detrimental effects of cyclic heating. Its hot ductility is very high and its hot strength is fairly good. It should not be used in sulfur-bearing gases where it has very poor resistance; also its resistance to molten ash or slag is very poor.

No. 37

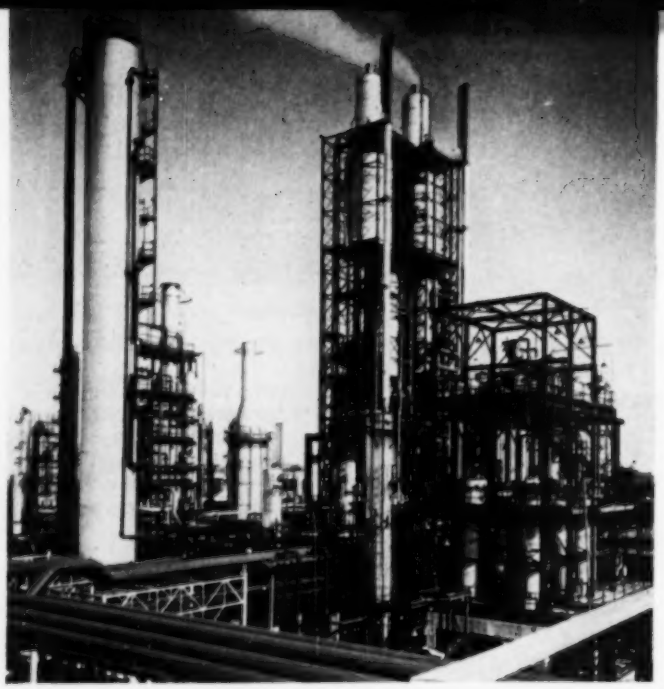
industrial news

A.E.C. APPROVES NUCLEAR PROCESSING STUDY

Acceptance of the first company-sponsored study of chemical and metallurgical processing problems associated with nuclear power systems was announced by the Atomic Energy Commission. The Vitro Corporation of America will investigate preparation of reactor fuel, removal of fissionable product poisons, primary separation of material discharged from the reactor, recovery and reworking of unspent fuel, recovery and decontamination of fissionable material produced in reactors, and radioactive waste disposal. A survey of available power studies and of the A.E.C.'s reactor development program will determine trends in processing requirements and the most probable lines of development and promising techniques and will enable estimation of the cost of projected design studies of nuclear power systems.

KNAPP EXPORTS TECHNICAL "KNOW-HOW" TO GERMANY

Knapp Mills Inc., has licensed Germany's leading producer of lead chemical equipment, Aug. Schnackenberg & Co., to use its patented processes and technical "know-how" in lead cladding. The agreement which is for an 18-year period, includes the automatic lead cladding machine invented by American Viscose Corp. and commercially developed by Knapp Mills along with four commercial processes not previously disclosed; one of which may be significant in the production of lead pipe normally extruded under thousand—ton presures. The arrangement is designed to bring specialized "know-how" to the industrial Ruhr.



NEW PETROLEUM EXTRACTION PROCESS USES SO_2

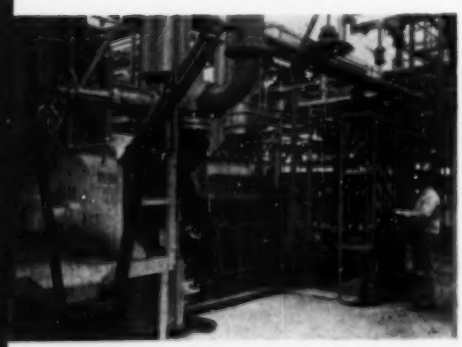
The simultaneous extraction of benzene, toluene and xylene from petroleum by the liquid sulfur dioxide process is being carried on for the first time by a refinery by Continental Oil Co. at Lake Charles, La. Mixing of sulfur dioxide with the catalytically reformed naphtha separates the oil into two portions: one a highly concentrated aromatic cut, and the other a highly paraffinic naphtha. The concentrated aromatic product is further separated to produce benzene and a mixture of toluene and xylene. The sulfur dioxide extraction unit, along with others involved in Continental's Lake Charles expansion program, was constructed and designed by Stone and Webster.

ORE UPGRADING UNIT INSTALLED IN CALIF.

New facilities for the upgrading of over 2 million tons of iron ore annually have been installed by Kaiser Steel Corporation at Eagle Mountain, Calif. Upgrading of the ore to a 56% iron content from a 51% content is accomplished by a dry magnetic separation of the high-grade magnetite ore followed by flotation of the lower grade ore in a mixture of water and ferrosilicon. Hematite, the sediment of the flotation, is combined with the magnetite.

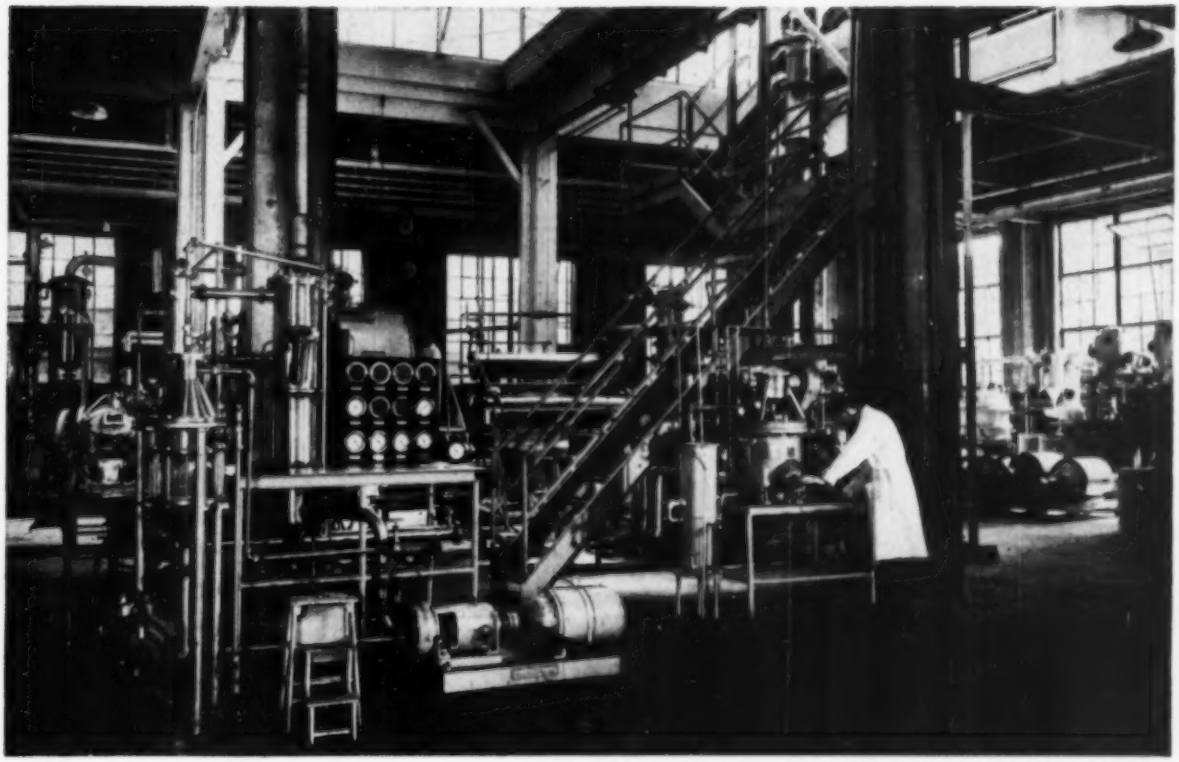
NON-CORROSIVE LIQUID PHOSPHATE SCHEDULED

A stable, non-corrosive ammonium phosphate solution for plant nutrient use is planned by Brea Chemicals, Inc. The new solution which can be safely handled and applied in aqua ammonia dispensing equipment is formed by mixing phosphoric acid with aqua ammonia. A new plant for the production of this chemical is being constructed at Brea, Calif., by the Macco Corp. The anticipated use of this chemical by western growers has stimulated plans for plants to be located at Brawley and Fresno, Calif.



CENTRIFUGAL COMPRESSOR INSTALLED IN TEXAS

The first use in any United States plant of a centrifugal ammonia condensing unit is in the Pasadena, Texas, plant of the Phillips Chemical Co. Two compressors driven by 2,500 hp. 9140 r.p.m. Worthington type "T" non-condensing steam turbines were installed by Chemical Construction Corp. These units provide 3,000 tons of ammonia refrigeration at 14° F. evaporator and 100° F. condensing temperatures. The heat of compression is reduced by liquid injection permitting use of six stages of compression in a single casing. Without liquid injection, it would have been necessary to install two casings in tandem.



Some of the Pilot Plant Equipment in the Buflovak Research and Testing Laboratory

. . . to find the best processing method pre-test your product in the Buflovak Testing Laboratory

To get full information about the most completely equipped processing laboratory in the world, write for your copy of Catalog 358.

When you're faced with a tough processing problem, you can pre-test both equipment and processes under production conditions in this Pilot Plant of the *Buflovak* Research and Testing Laboratory.

These facilities plus experienced engineers and technicians are maintained to help you solve problems in drying, evaporation, extraction, solvent recovery, crystallization, and food processing . . . including low-temperature evaporation and drying, and other advanced processes that lead to improved operations.

The tests range from a few beakers of precious chemicals and antibiotics to tank cars of material requiring round-the-clock operation on a production scale. The data obtained from this pre-testing has resulted in the right answer to more than 7000 processing problems in the chemical, food, pharmaceutical and similar industries.

When you want to pre-test a new process to determine what equipment to use or to improve your present processing method, ask *Buflovak*. We'll be glad to make our Pilot Plant facilities and our engineering staff available to help you. The results will be held in strictest confidence.

BUFLOVAK EQUIPMENT DIVISION
BLAW-KNOX COMPANY
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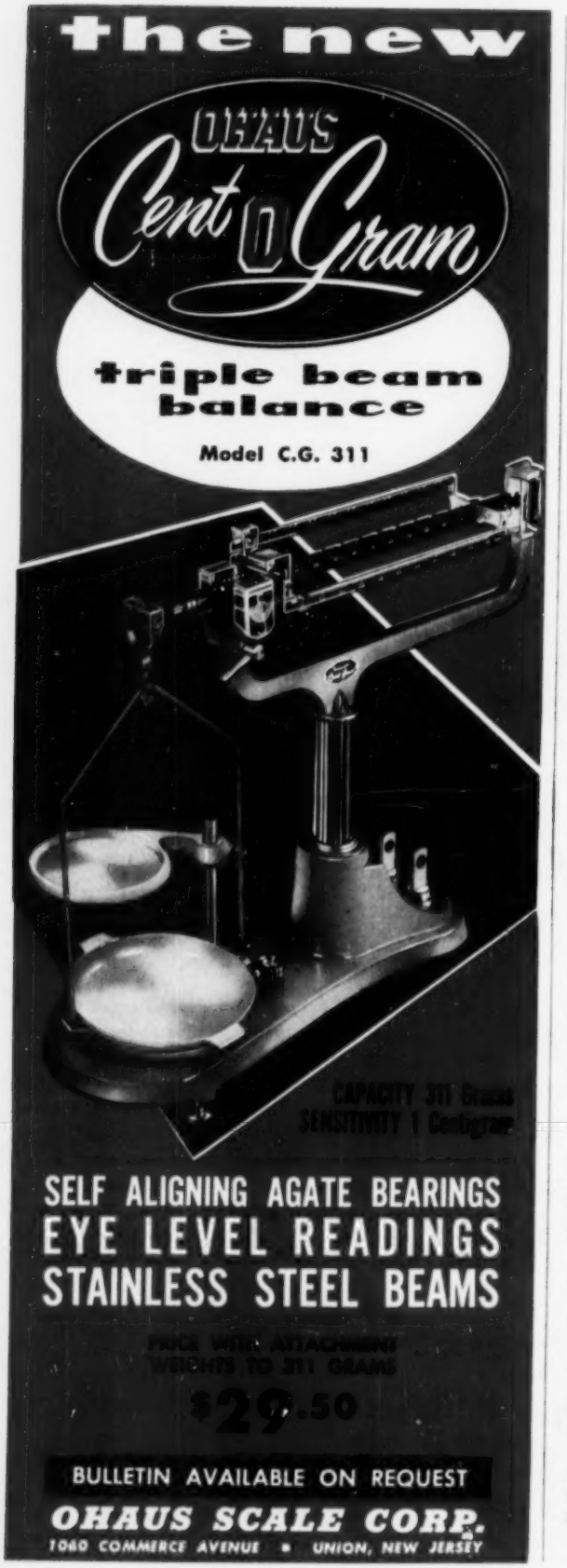
BUFLOVAK PRODUCTS: evaporators • dryers (atmospheric and vacuum) • solvent recovery and distillation equipment • chemical plant equipment • food processing equipment • kettles • fabricated processing equipment • vulcanizers . . . plus a complete Pilot Plant for pre-testing processes and products.



CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

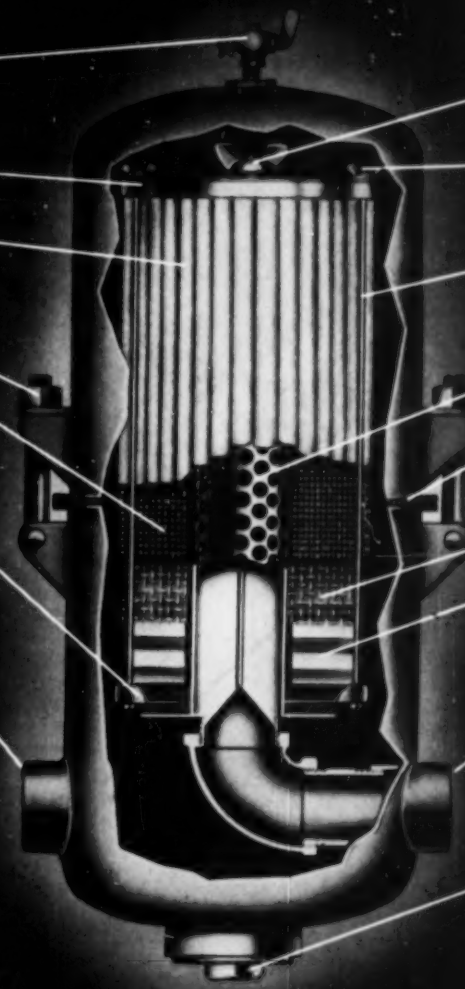
These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members will receive careful consideration if received before October 15, 1954, at the Office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Associate

Acheson, Howard A., Jr., *Newark, N. J.*
Alliston, John W., *Baytown, Tex.*
Andrews, Jerry G., *Oak Ridge, Tenn.*
Baczewski, Matthew, *Jamaica, N.Y.*
Benz, August, *Portland, Ore.*
Beverly, Robert G., *Rifle, Colo.*
Bischak, Robert E., *Monaca, Pa.*
Bossung, Robert B., III, *Louisville, Ky.*
Brandes, Raymond L., Jr., *Manasquan, N. J.*
Byrne, Earl B., *Cincinnati, Ohio*
Carhart, E. Marter, III, *Old Greenwich, Conn.*
Carlin, Owen Bryant, *Rutherford, N. J.*
Cerra, Orlando J., *Homestead, Pa.*
Chalela, Daniel Aljure, *Bogota, Columbia, S. A.*
Chambers, Ralph L., Jr., *Cumberland, Md.*
Chu, Franklin, *Saratoga Springs, N. Y.*
Cohen, William C., *Brooklyn, N. Y.*
Collier, Alan Roger, *Augusta, Ga.*
Cooper, John E., *Hopewell, Va.*
Dailey, Joseph John, Jr., *Danville, Pa.*
Dojer, Antonio, *Managua, Nicaragua, C. A.*
Davies, William A., *Houston, Tex.*
Davis, Jerry P., *Miami, Fla.*
DeBoer, Duane D., *Mitchell, Neb.*
deNevers, Noel, *San Francisco, Calif.*
Dennett, Robert F., *Niagara Falls, N. Y.*
Dimitri, Mitchell S., *Charleston, S. C.*
Donovan, Leo F., Jr., *Millburn, N. J.*
Dranoff, Joshua, *Bridgeport, Conn.*
Easterling, Dudley, *Lawrenceburg, Ind.*
Engle, Paul M., Jr., *Clay, N. Y.*
Ericson, Richard, *Evanston, Ill.*
Esral, Abe, *Atlanta, Ga.*
Field, Rodney J., *Columbus, Ga.*
Fischer, George I., Jr., *Los Angeles, Calif.*
Fitzgerald, John A., *Charleston, W. Va.*
Fleetham, George H., *Wyandotte, Mich.*
Flickinger, R. C., *Pasadena, Tex.*
Fourrier, Lionel J., *Lake Jackson, Tex.*
Gardin, George F., *Hudson, Mass.*
Gentles, Thomas K., *New Castle, Del.*
Grigorieff, W. W., *Oak Ridge, Tenn.*
Grobman, Jack Sidney, *Lakewood, Ohio*
Gruverman, Irwin J., *Brooklyn, N. Y.*
Guobis, Joseph Thomas, *Richmond Hill, N. Y.*
Hafstad, Jakob, *Chattanooga, Tenn.*
Haller, Edwin N. Jr., *Franklin, La.*
Hanson, James S., Jr., *Hyde Park, Mass.*
Hathaway, Robert S., *Evanston, Ill.*
Heimlicher, Bruce Leonard, *North Plainfield, N. J.*
Hellwig, Katherine Carlisle, Mrs., *Austin, Tex.*
Henry, Charles E., *Akron, Ohio*
Hill, George G., *Ellsworth, Me.*
Hirschbeck, Edward O., *Akron, Ohio*
Hlavin, Robert, *Long Beach, Calif.*
Hoffman, R. Glenn, *Sewickley, Pa.*
Holcomb, Frank M., *Waterloo, N. Y.*
Jacobsen, P. J., *Grandmere, Que., Canada*
Jentz, Norman E., *Cleveland, Ohio*
Johnson, Donald R., *Alhambra, Calif.*
Kelleher, David, *Yonkers, N. Y.*
Kelly, Marvin C., *Queens Village, N. Y.*
Killen, James R., II, *Menlo Park, Calif.*
Kolowsky, Donald E., *New York, N. Y.*

(Continued on page 45)



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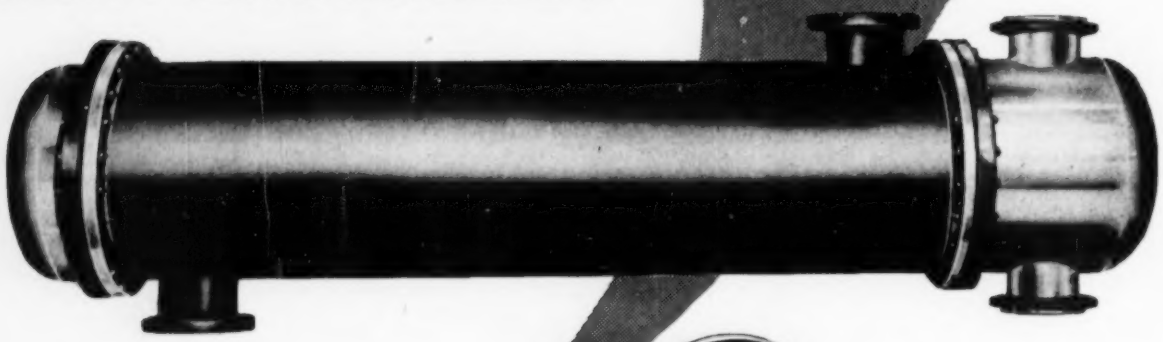

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(Continued from page 42)

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Kuong, Javier F., *Wilmington, Del.*
Lakotish, Donald M., *Parma, Ohio*
Leavitt, Sydney R., *Dutremont, Que., Canada*
Lecuona, Julio, *Havana, Cuba*
Lee, George C-Y, *Silver Spring, Md.*
Liston, Edward M., *Los Altos, Calif.*
Little, Albert P., *Boston, Mass.*
Liu, Yung T., *Springfield, Ore.*
Lowenstein, Philip, *Linden, N. J.*
Lynn, John R., Jr., *Ponca City, Okla.*
Magistro, Michael Louis, *Dhahran, Saudi Arabia*
Malter, Lewis, *St. Louis, Mo.*
Mangan, Thomas N., *Wollaston, Mass.*
McKinney, William D., *Memphis, Tenn.*
McMillan, Vernon J., *Texas City, Tex.*
McWilliams, Cleo Paul, Jr., *Louisville, Ky.*
Moffett, Glendon L., *Brookline, Mass.*
Molinary, Charles J., *Brooklyn, N. Y.*
Nagel, Henry William, *Leonia, N. J.*
Nichols, Cecil E., Jr., *Orangeburg, S. C.*
Nielsen, Walter H., *Midland, Mich.*
Nix, Paul S., Jr., *Jersey City, N. J.*
Owen, Archibald A., III, *Lewisburg, Pa.*
Papastrat, Harry J., *Poughkeepsie, N. Y.*
Passigli, Dario, *Brooklyn, N. Y.*
Peake, Stephen L., *Pittsburgh, Pa.*
Perret, Joseph D., Jr., *New Orleans, La.*
Petras, Edward F., *Glassport, Pa.*
Pfeifer, Carl E., Jr., *East St. Louis, Ill.*
Pointon, Robert A., *Trenton, N. J.*
Price, William R., Jr., *Elizabeth, N. J.*
Puckett, Lee M., *Louisville, Ky.*
Rasmussen, George H., *Neenah, Wis.*
Ravicz, Arthur E., *Austin, Tex.*
Raycob, J. Paul, *Baltimore, Md.*
Reuter, Edward Allen, *Milwaukee, Wis.*
Reynolds, Guy E., *Indianapolis, Ind.*
Richardson, Raymond C., *Denver, Colo.*
Rissmiller, Edwin H., *Morristown, N. J.*
Ross, Allen S., *Memphis, Tenn.*
Rubin, Barney, *Livermore, Calif.*
Russell, Harold W., Jr., *Niagara Falls, N. Y.*
Rutz, Lenard, *New Castle, Del.*
Sanborn, I. Bruce, *Appleton, Wis.*
Sanders, Charles F., Jr., *Louisville, Ky.*
Schauberger, George, *Louisville, Ky.*
Schaus, Orland, *Niagara Falls, Ont., Canada*
Schmitt, Peter, *Bogota, Colombia, S. A.*
Schooley, Arthur Thomas, *Camp Hill, Pa.*
Schuppert, Kenneth M., *Louisville, Ky.*
Schwartz, Harvey J., *Cleveland, Ohio*
Scotti, Louis Joseph, *Ozone Park, L. I., N. Y.*
Sikchi, K. G., *Pittsburgh, Pa.*
Sillett, Francis M., *Marcus Hook, Pa.*
Smith, Charles H., *Chicago, Ill.*
Snakenberg, Randolph F., *Pasadena, Tex.*
Speck, George A., *Texas City, Tex.*
Stanek, Wencil M., *Baton Rouge, La.*
Strang, Roger P., *Las Vegas, Nev.*
Stroud, Arthur H., *Two Rivers, Wis.*
Taipale, Waino A., *New York, N. Y.*
Thompson, A. E., *Barberton, Ohio*
Thompson, John E., *Chicago, Ill.*
Touchette, Robert V., *Rumford, Me.*
Traeger, Richard K., *Milwaukee, Wis.*
Trinker, Thomas, *Norco, La.*
Trivison, Mark E., *Nitro, W. Va.*
Van Wormer, Frances W., *Richland, Wash.*
von Rosenberg, H. C., *Houston, Tex.*
Wilkinson, Bruce W., *Midland, Mich.*
Wilson, Robert C., *Washington, D. C.*
Wulf, W. H., *El Cerrito, Calif.*
Wylie, John E., *Flushing, N. Y.*
Zotos, John, *Brockton, Mass.*

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Dinsmore, Elgie B., *Pasadena, Tex.*
Donahue, N. J., *Aiken, S. C.*
Kaszynski, Richard D., *Toledo, Ohio*
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The Third Convention of the Pan American Federation of Engineers (U.P.A.D.I.)

DELEGATES VISIT SAO PAULO PLANT

Left to right: G. A. Hathaway; G. O. G. Lof, A.I.Ch.E.; R. A. Morgen, A.I.Ch.E.; M. Smith, Guide.

The Third Convention of U.P.A.D.I. was held at Engineers Club of Sao Paulo, Brazil, from Aug. 2 through Aug. 6, 1954. This meeting provided a fine opportunity for the engineers of the Americas to meet and to knew one another better. Engineers Joint Council is the official agency of the United States for representation at U.P.A.D.I.

The United States had ten delegates from E.J.C. representing the various member societies. James M. Todd (A.S.M.E.) was chairman of the U. S. delegation and General Stewart E. Reimel, Secretary of E.J.C. was one of the delegates. George O. G. Lof and Ralph A. Morgen were the A.I.Ch.E. members appointed as official delegates.

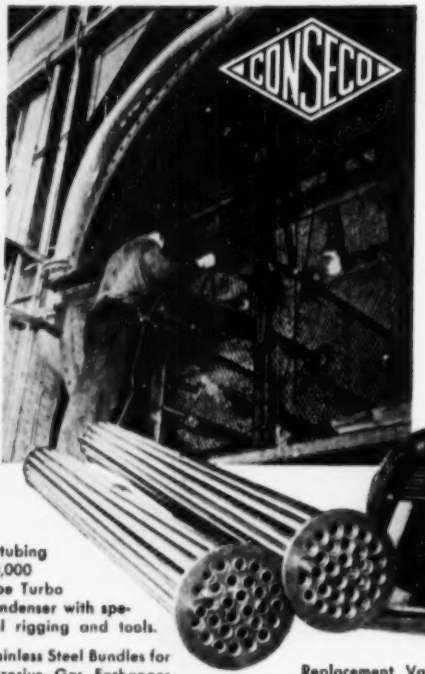
The five major committees were: (1) Administration, (2) Relationship, (3) Legislation, (4) Budget, and (5) Technical Matters. The Educational Subcommittee was under the latter and the writer was involved in the work, as were the two National Science Foundation grantees.

The weakness of U.P.A.D.I. has been the lack of a specific program or objective. However, if some of the recommendations made in the resolutions could be activated, the organization would undoubtedly be strengthened. Future meetings could thus be made more meaningful. Its strength, on the other hand, is the better understanding among the engineers and the building of a bond between the countries represented. The governor of the State of Sao Paulo, Lucas Noguera Garcez, accepted the Honorary Chairmanship and graciously entertained the delegates at a formal reception. Goveronr Garcez is on leave of absence from the Chair of Hydraulic Engineering at Sao Paulo University.

Some of the more significant resolutions passed by the Convention were:

1. From the Committee on Administration
   - A. Publish a bulletin to knit together the U.P.A.D.I.
   - B. Have an official correspondent in each country.
2. From the Committee on Legislation:
   - A. Cooperate with and receive information from the Organization of American States (O.A.S.).

(*Continued on page 77*)



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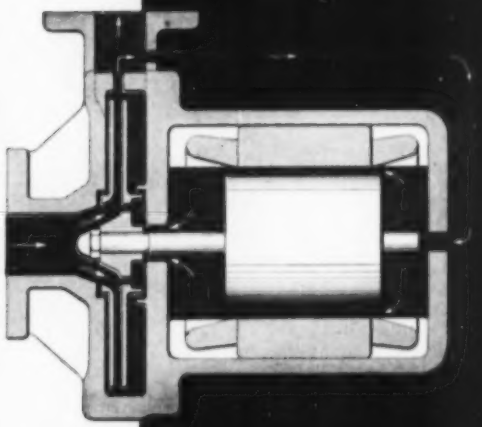

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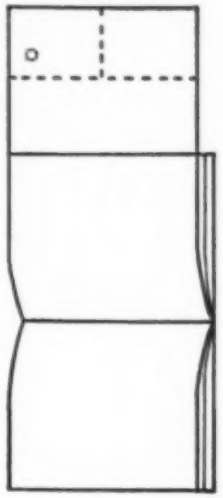

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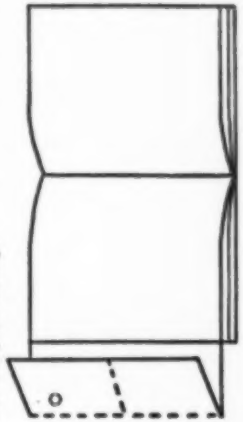

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Advertisers' Products

IFC	3R	4L	5A	6L	7A	8A	9A	10A
11A	12A	13A	14L	15A	16A	18A	19A	21A
22A	23A	24L	24R	25R	26A	27A	28A	29A
30A	31A	32L	33A	34A	430A	37A	38A	41A
42L	43A	44A	45T	45B	46B	47A	48A	53A
57A	59A	60A	62L	63A	64L	65A	66L	67A
68L	69R	70L	71R	72L	73R	75R	76L	76TR
77R	78L	78TR	78BR	79R	80T	80B	81R	82T
82B	83TL	83BL	83R	85T	85B	86T	86B	87B
IBC	OBC							

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September, 1954

PRODUCTS (*Continued*)

62L **Force Feed Lubricators.** Models available for operation against discharge pressures of up to 30,000 lb./sq.in. gauge. Manzel Division of Frontier Industries, Inc.

63A **Celite Filtration.** Powders may be used with any type of conventional filter. For antibiotics, food products, chemicals, etc. Johns-Manville.

64L **Drying Research.** Dryers, with each variable adjusted as desired. C. G. Sargent's Sons Corp.

65A **Nickel Steel for Valves.** Nickel increases resistance of steel to sub-zero embrittlement. The International Nickel Co., Inc.

66L **Mist Eliminators.** Factory cut to fit vessel dimensions and contours. Can be made of practically any metal, to combat corrosion. Metal Textile Corp.

67A **Experimental Production.** Complete pilot plant, priced less than $8,000. Also standard glassed steel columns from 2-in. (diameter) to 48-in. The Pfaudler Co.

68L **Valves.** Gate, globe and swing check valves to meet material specifications. Pacific Valves, Inc.

69R **Tank Heaters.** Finned construction provides approximately 7 times more heating surface per foot of tube length than plain bare pipe. Brown Fintube Co.

70L **Double Cone Blender.** For mixing of dyestuffs, and industrial chemicals, pharmaceuticals, food stuffs, etc. Paul O. Abbé, Inc.

71R **Conductivity Cells.** Complete line of conductivity measuring and control equipment. Industrial Instruments, Inc.

72L **Catalyst.** For removal of carbon monoxide from hydrogen. The Girdler Co.

73R **Propeller Pumps.** Propeller or axial flow pumps to circulate large volumes of liquid or slurry against low heads. Lawrence Pumps, Inc.

75R **Teflon made by Ethylene.** Extruded or molded rods, tubes, and special shapes. Non-porous sheets. Ethylene Chemical Corp.

76L **Antifoam A.** Odorless and tasteless, silicone defoamer is physiologically harmless in foods at concentrations up to 10 p.p.m. Also Antifoam AF, a dilutable defoamer containing 30% Antifoam A. Dow Corning Corp.

76TR **Alloy Fabricators.** Stainless steel, monel, inconel, nickel and aluminum process equipment. Alloy Fabricators Div. of Continental Copper and Steel Industries, Inc.

77R **Exchangers.** A graphite tube side, steel shell side exchangers, falling film evaporators. Also coolers. The Whitlock Manufacturing Co.

78L **Dry Grinding Units.** Self-contained and portable, 7 ft. 8 in. high. Also wet grinding units. Hardinge Co., Inc.

78TR **Filter Media.** Engineered for optimum efficiency in handling countless exposure condtions. Micro Metallic Corp.

78BR **Steam Jet Ejectors.** Condensers and vacuum equipment. Corrosion resistant parts interchangeable with standard parts. The Jet-Vac Corp.

79R **Plastic Pumps.** For difficult corrosive solutions and abrasive slurries. Vanton Pump & Equipment Corp.

80T **Pilot Plants to Processing Equipment.** Manufacture of full range of chemical processing equipment. Artsian Metal Products, Inc.

80B **Filter Presses.** Chambers may be added or removed for expanded or reduced capacity. T. Shriver & Co., Inc.

81R **Saunders Patent Diaphragm Valves.** Bodies of Polyvinyl Chloride. Sizes range from ½ in. through 2 in. Hills-McCanna Co.

82T **Skin Barrier Cream.** Indicated to offer skin protection against irritants and sensitizing agents encountered in industry. Ayerst Laboratories.

82B **Corrosion-Resistant Mortars.** For acid- and alkali-proof masonary in floors, tanks, sewers, towers, etc. Delrac Corp.

83TL **Unit Spray Dryer.** Stainless steel construction, light weight, small area installation. Foster D. Snell, Inc.

83BL **Stainless Steel Products.** Buckets, 8 in. pipe, Woodruff keys, pipe fittings, valves, cotter pins, nuts, wood, screws, etc. Schnitzer Alloy Products Co.

83R **Double Cone Blender.** Retractable charging and unloading device. Brake for accurate positive positioning. Motor or floor mounted. General Machine Co. of New Jersey.

85T **Filters.** Features new catalog on filtration and its application. D. R. Sperry & Co.

85B **Plasticizer Oil.** Compatibility with GRS, neoprene, and buna N type rubbers. Pan American Refining Corp.

86T **Laboratory Crushers.** Rolling ring or hammer type rotors to handle specific reduction job. Send samples for testing. American Pulverizer Co.

86B **Pumps.** Constructed to withstand abusive service. Horizontal and vertical shaft types. Nagle Pumps, Inc.

87B **Evactors.** Illustration shows two 4-stage evactor units in pharmaceuticals plant. Also jet mixers, jet heaters, etc. Croll-Reynolds Co., Inc.

IBC **Flow Control Pumps.** Bulletin describes application of flow control pumps to chemical feed and complete instrumentation systems. Milton Roy Co.

OBC **Pilot Plant Mixers.** Also description of "Lightnin" mixers of all sizes. Mixing Equipment Co., Inc.

CHEMICALS

1 **Anion Exchange Resin.** Titled "Acid Adsorption with Duolite A-7 Anion Exchange Resin," brochure from Chemical Process Co. Details technical aspects of resin & uses. Sections on common traits, porosity, thermal stability, preparation of acid influents & physical considerations.

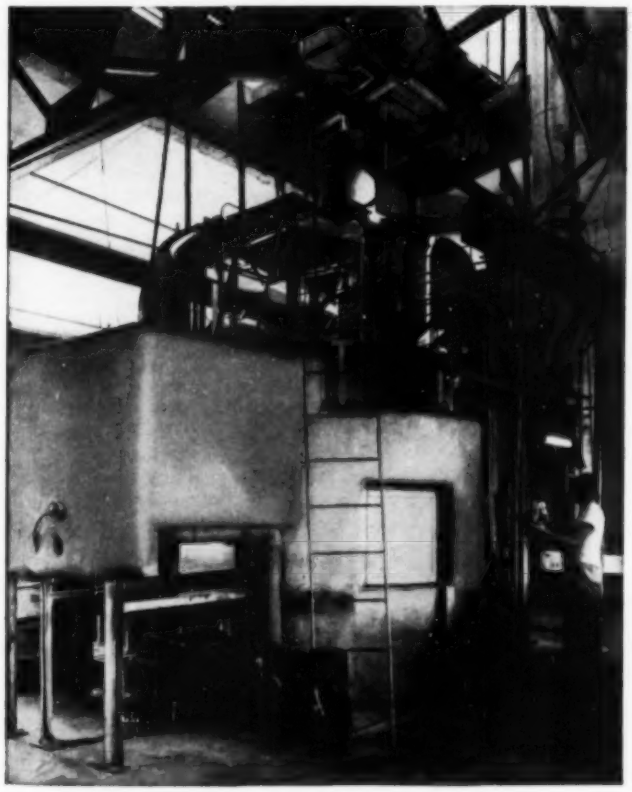
2 **Vinyl Coatings.** Basic data on Polyclad vinyl coatings for maintenance painting given in bulletin from Carboline Co. division Mullins Non Ferrous Castings Corp. Films of 5 mils. (.005") on vertical surfaces. Information on use, temperature limits, thickness & coverage, weathering ability & cost.

(Continued on page 54)

SPRAY DRYER PIONEER

American Lava meets difficult problem of fine blending and homogenuity by use of Bowen Spray Dryer

American Lava Produces First Spray Dried Titania Dielectric Material



Operator at the controls of Compact Bowen Spray Dryer producing titania dielectric product.

A desire for a higher quality product led American Lava to experiment with various methods of producing a finely blended homogenous titania material suitable for extrusion of special dielectric parts. Ordinary wet blending and subsequent drying previously used in this field did not produce the required uniform product.

American Lava was the first to use spray drying to solve the problem. Materials are now wet blended in a ball mill and then fed to the spray dryer. A finely blended homogenous product subject to infinite control of the dielectric properties is the result.

Bowen Engineering is proud to have had the opportunity to cooperate in this project.

Write today for Illustrated Booklet
"The Bowen Story of Spray Drying"

BOWEN ENGINEERING, INC.
NORTH BRANCH 13, NEW JERSEY

Recognized Leader in Spray Dryer Engineering Since 1926

BOWEN SPRAY DRYERS
Always Offer You More!

3 **Acetoacetarylamides.** Published by Carbide and Carbon Chemicals Co. technical information sheet on aceto-acetarylamides used in pigments such as Hansa & benzidine yellows. Are not darkened by atmospheric sulfur. Resemble ethyl acetoacetate in chemical reactivity. Susceptible to condensation & substitution reactions characteristic of compounds containing reactive carbonyl & methylene groups.

4 **Surface Active Chemicals.** New series of surface active chemicals based on lignin introduced by Polychemicals Division of West Virginia Pulp and Paper Co. Called Polyfons surface active properties said to suggest possibilities in water base drilling muds, treating feed water, etc. Bulletin gives concentrations, other data.

5 **Colloidal Dispersions.** From Acheson Colloids Co. 4-page booklet listing 40 dispersions of colloidal graphite, molybdenum disulfide, vermiculite & zinc oxide. Applications, densities, carriers listed. Recent additions offer advantages as bases for 'dag' colloidal graphite & molybdenum disulfide dry-film coatings.

6 **Synthetic Methanol.** Illustrated 16-page booklet from Carbide and Carbon Chemicals Co. on synthetic methanol. For use by chemists, engineers, purchasing agents. Data on uses, physical properties, specifications, specific gravities, viscosities. Applicable in production of anti-freeze, phamaceuticals, dyes, fuels, adhesives, refrigerants.

7 **Surfactant.** Petro AA a surfactant developed by Petrochemicals Co. said to have outstanding solubility, effectiveness & stability in concentrated acids & alkalies. Available as powder or liquid in commercial quantities. Technical bulletin gives details on properties, etc.

8 **Derivatives.** Aliphatic & sodium derivatives are subject of booklet from Humphrey-Wilkinson, Inc. Lists compositions, reactions, all pertinent information.

9 **Conversion Chart.** From Monsanto Chemical Co. comprehensive wall chart showing chemical methods for converting acrylonitrile into more than 100 derivatives. Arranged in sequential form presents methods for synthesis in three classifications: cyanoethylation, nitrile, & olefinic reactions.

10 **Vinsol Resin.** Technical booklet containing wide range of data relative to use of Vinsol resin as low-cost component of Buna-N, vinyl, other type adhesives available from Hercules Powder Co. Resin is hard, brittle, high-melting thermoplastic material derived from southern pine wood. Two sections on product applications.

11 **Silicone Rubber Polymers.** Dow Corning Corp. basic silicone rubber polymer called 400 Gum. Said to be clear, uniform, nontoxic. A dimethyl silicone gum of high molecular weight & viscosity. Easy to handle, stable in storage, requires no preliminary breakdown. Williams plasticity 45 mils; specific gravity at 25° C. is 0.98. Binder on material includes details, graphs, properties, compounding information.

12 **Lignin-Synthetic Rubber Coprecipitate.** From West Virginia Pulp and Paper Co. Indulin-70-Gr-S a lignin-synthetic rubber coprecipitate for service as a reinforcing agent. Said to be first instance of industry processing of Gr-S latex into dry masterbatch. Experience shows cured rubber stocks using this material have high tensile strength, good water resistance, excellent flex life & low flex crack growth. High tear resistance. Technical bulletin gives complete information.

14 **Calcium Lignosulfonate.** Toranil a de-sugared calcium lignosulfonate subject of folder from Lake States Yeast Corp. Two forms, Toranil A available now only in 8,000 gal. tank car lots. Toranil B in 50 lb. bags.

15 **Nitroparaffins.** Technical data sheet from Commercial Solvents Corp. on nitroparaffins including nitromethane, nitroethane, 1-nitropropane & 2-nitropropane. Also gives specifications, physical properties, chemical reactions.

16 **Chlorinated Benzenes.** Handbook from Dow Chemical Co. on "Chlorinated Benzenes," for use in laboratory, research production, or purchasing departments. Described are monochlorobenzene, o-dichlorobenzene, p-dichlorobenzene, 1,2,4-trichlorobenzene. Includes derivative charts, end uses, property & solubility tables & toxicity & handling precautions.

17 **Ethyl Benzene.** From Carbide and Carbon Chemicals Co. ethyl benzene a high purity compound for syntheses & solvent uses, now available in tank car quantities. Said to be outstanding for vinyl-type polymerizations because of active chain transfer agent & promotion of low molecular-weight resins. Medium evaporation rate & good solvent power valuable in coating resins. Suggested raw material for dyestuffs & detergents. May also be used as extraction solvent.

BULLETINS

25 **Welded Steel Barges.** All types of welded-steel barges for river & harbor use described in illustrated booklet from Dravo Corp. One section devoted to descriptive data and pictures of tank barges used in chemical & petroleum industries to transport large quantities of liquid cargo to terminals & plants along inland & coastal waterways.

26 **Steam Traps.** "Solving Steam Trap Problems" is title of revised catalog from V. D. Anderson Co. Includes information on new combination float & thermostatic traps said to vent air in one-eighth time of standard inverted bucket traps. Specifications, capacities, selection data.

27 **Porcelain Equipment.** Lapp Insulator Co., Inc. 24-page bulletin on line of chemical porcelain equipment for process applications. Includes Y & single valves, safety valves, plug cocks, pipe & fittings, towers & tower plates, nozzles, & Raschig rings. Two pages on Tufclad armoring for Lapp equipment. Also on Epon resin impregnated Fiberglas covering.

28 **Direct-Coupled Pumps.** Dealing with selection of proper motorpump for specific jobs is booklet from Ingersoll-Rand. Actual slide-film presentation in book form. Describes centrifugal pump & how it works, & points out various factors, including quantity, pressure, friction losses & head—all considerations in pump selection.

29 **Heat Exchanger.** Type-UF heat exchanger product of Thermal Research & Engineering Corp. described in bulletin No. 105. Available for pressures of 300 lb./sq.in. gauge & temperature of 1,200° F. Other types avaliable. For use in chemical processing & jet engine component testing work.

30 **Steel Castings.** Illustrated 32-page brochure from Lebanon Steel Foundry tells the story of entire process of steel casting manufacture from design & engineering to final phase. Brief history of company is followed by development of early Circle-L product.

31 **Cycloflow Valves.** A four-position single-control valve for regulation of flow through ion-exchange equipment. American Water Softener Co. booklet describes function, operation, design, construction, other features. Available in sizes 1½ to 4 in.

32 **Flexible Couplings.** Lovejoy Flexible Coupling Co. couplings are subject of illustrated bulletin showing types & sizes for every service. Included are specifications & dimension charts, schematic drawings, much other pertinent information.

33 **Non-Plug Crushers.** Jeffrey Mfg. Co. crushers for reducing all types of wet, sticky materials described in illustrated bulletin. Six sizes. Schematic diagrams, general specifications, other information.

34 **Flexible Tubing.** Ace-Flex all-purpose plastic tubing with good flexibility & clear transparency now available from American Hard Rubber Co. Bulletin includes physical properties, chemical resistance, sizes, characteristics. Suggested for use in chemical processing laboratory, medical & other industrial uses.

35 **Protective Coatings.** For corrosion control & heavy duty maintenance painting, Ucilon protective coatings from United Chromium, Inc. Folder lists case histories, table of 100 corrosives which material resists, other information.

36 **Heat Exchangers.** Bulletin from Davis Engineering Corp. on Paracoil heat exchangers for chemical & industrial process applications. Technical descriptions, illustrations.

37 **PeriFilter System.** Dorr Co. Bulletin on Aldrich PeriFilter system. Combines in single unit, pre-treatment & filtration of industrial water supplies. Composed of pre-treatment mechanism surrounded by annular rapid sand filter. Includes hydraulic or motor operated control valves, filter rate controllers, instrument & panel boards for manual or automatic operation & control. Removes color, hardness, iron, manganese, or turbidity from raw water in pre-treatment compartment, residual turbidity & bacteria in sand filter.

38 **Stainless Steel.** Second edition of Allegheny Ludlum Steel Corp. booklet on "Allegheny Metal in Chemical Processing." Covers use of stainless steel in manufacture of acids & other chemicals, general process industries, plastics industry, pharmaceutical manufacture, dye & soap making. Corrosion resistance data, fabrication information, stainless steel finder included.

39 **Thermocouples & Packing Glands.** Catalog from Conax Corp. illustrates & describes line of products including bare wire thermocouple glands, packing glands, protection tubes, other thermocouples & glands. Bare wire thermocouple glands said to provide lower mass & faster response & are available with neoprene, Teflon or powdered talc sealants. Advantages, construction detailed.

40 **Continuous Level Indicator.** Fielden Instrument division of Robertshaw-Fulton Controls Co. bulletin on Telstor electronic continuous level indicator. Simplified circuitry, accuracy ±2% with continuous indication at remote local stations. No moving parts to stick or foul. Measures level of interface of materials having dissimilar dielectric constants.

41 **Wall Frame Chart.** Because of revised frame standards by NEMA, Reliance Electric & Engineering Co. has issued a "Compar-A-Frame" wall chart. For use in design and layout of equipment. Shows comparative dimensions of open & fan-cooled type polyphase induction motors. Sub-charts for comparison of frame sizes according to horsepower & speed, plus chart of dimensions of old & new frames. Two simplified motor outlines for essential dimensions, key to letters.

42 **Unions & Swing Check Valves.** New edition of Catawissa Valve & Fittings Co. catalog on unions & swing check valves. Sections on materials & methods, various types & weights, test data chart, etc. Available in forged carbon steel, carbon-molybdenum, chromium-molybdenum, and 188 stainless steel, etc.

43 **Teflon Gaskets.** Catalog United States Gasket Co. on Chemiseal gaskets & accessories for all chemical resistant piping & equipment. Impervious to all chemicals except molten alkali metals, fluorine at high temperatures & chlorine trifluoride. Special shapes available.

44 **Two-Stage Centrifugal Pumps.** Worthington Corp. bulletin on type UNB two-stage centrifugal pumps for pressures to 400 lb./sq.in. & capacities to 1300 gal./min. Variety of material with fittings in bronze, iron & stainless steel. Water-cooled, water sealed stuffing box. Dimensions, charts, materials of construction, cross-sectional views.

45 **Diaphragm Motor Valves.** Minneapolis-Honeywell Regulator Co. series 800 line of diaphragm motor valves with double or single seated, low flow, Venturi & 3-way bodies. Specifications & features of each type given.

46 **Valves.** For instrument piping & general use, binder insert on Jerguson Gage & Valve Co. valves for instrumen piping & general use. Contains illustrations & drawings on how valves combine unions, nipples, reducers, elbows, tees.

47 **Vibrating Conveyor.** From Gifford-Wood Co. bulletin on the Oscilveyor vibrating conveyor. Describes operation & lists features which add to its desirability for handling fine granular materials. Dimensioned drawings plus information correlating pan size with travel speed of material.

48 **Water Treatment.** Allis-Chalmers Mfg. Co. binder insert bulletin discusses water treatment for cooling towers. Also corrosion of metal surfaces, inorganic scaling, organic growths such as algae & bacterial slime, & delignification of wood in the tower. Table shows type & amount of treatment effective for prevention of scale or corrosion under specific operating conditions.

49 **Solenoid Valve—Refrigeration Information.** (49) Binder
50 section bulletin on refrigeration valves, filters, driers from A-P Controls Corp. Complete data on construction, dimensions, product features on four types of valves. (50) Section on model 73 solenoid valve for refrigeration & industrial applications. May be used with non-corrosive liquids, air or refrigerants. Four body styles in ⅜- & ½-in. sizes.

51 **Pressure Transmitters.** Swartwout Co. Autronic differential pressure transmitters described in bulletin. Features are no zero shift due to static pressure variation, easily adjustable, no electric motors. No slide wires, or vacuum tubes. Parts in contact with fluid may be made of materials to operate under most corrosive conditions. Cross-sectional views.

52 **Aircheck Valves.** Nine reasons for use of Aircheck valve in compressor installations set forth in illustrated bulletin from Pennsylvania Pump & Compressor Co.

53 **Kel-F Valve Diaphragms.** Increased diaphragm life & reduction in maintenance of Saunders valve results from valves handling active organics with thermally stabilized plasticized Kel-F plastics. After 90 days of countless open & close cycles, diaphragms are still flexible. No sticking present & positive fluid control maintained. M. W. Kellogg Co.

54 **U-Tube Mechanical Flow Meter.** Penn Industrial Instrument Corp. catalog on redesigned tilting U-tube mechanical flow meter. Conforms to present panel instrumentation. Basic principle of operation remains same. Pertinent data given including description of operating principle, easy calibration method, convenient range change feature, capacities, pressures, materials of construction.

55 **Industrial Instruments.** Binder insert catalog No. 5000 from Minneapolis-Honeywell Regulator Co. describes in brief the principal types of industrial instruments in their line. Includes pyrometers, flow & liquid level meters, thermometers, gauges & panelboards.

56 **Viscometer Handbook.** Titled "Solutions to Sticky Problems" handbook from Brookfield Engineering Laboratories concerns use and operation of their products to best advantage.

57 **Level & Pressure Control.** Bulletin on Chronoflo level & pressure telemeter from Builders-Providence, Inc. Describes application to level control in reservoirs & elevated & ground storage; pressure control in discharge lines; booster stations, & automatic pump control. Descriptions & illustrations plus diagrams of installation arrangements.

58 **Expansion Joints.** Gun-Pakt expansion joints can be serviced without unpacking. Folder from Yarnall-Waring Co. gives facts on conventional & gland-packed joints & Yarway Gun-Pakt joints.

59 **Rotary Vacuum Filters.** Continuous filtration with Filtration Engineers Inc. rotary vacuum filters is subject of illustrated bulletin. Discusses operation, construction, filter cloth, sizes. Diagrams show several basic installations. Available on rental-purchase plan.

60 **Manual Starting Switches.** On & off snap switch combined with thermal overload device. Provides more wiring space, easily accessible terminals. Fully enclosed. Bulletin 600 from Allen-Bradley illustrates various available types.

61 **Plastic Pumps.** Vanton Pump & Equipment Co. bulletin on flex-i-liner plastic pumps contains cutaway illustrations, data on application, specifications, corrosion resistance. No stuffing boxes or shaft seals, self-lubricating, high vacuum, no gaskets.

62 **Dispersion Mill.** Published by Kinetic Dispersion Corp. manufacturers of the Kady Mill, brochure discusses dispersion in chemical processes & industry. Approach is from practical & theoretical viewpoints plus studies on materials behavior in solid, liquid & dispersional phases. Many illustrations plus technical data.

63 **Stainless Filters.** All types of stainless steel filters covered in bulletin from Cherry-Burrell Corp. Three models meet every filtering need. Said to assure cleaner, better tasting product. Flow rate 3,000 to 4,000 lb./hr. Double units handle 6,000 to 8,000 lb./hr.

64 **Engineering Data Book.** Revised second edition of Rempe Co. Engineering data book on pipe & fin coils, now available. For use by design engineers & plant superintendents. Specific data on subjects of dimensional limitations, coil development formula & heat transfer factors.

65 **Ampco Machining Bulletin.** From Ampco Metal, Inc. revised edition of their bulletin "The Machining of Ampco Metal." Gives case histories & experiences on machining of this metal in all phases.

66 **Pulva-Sizers & Com-Bin Feeders.** Revised catalog from Pulva Corp. illustrates both lines. Pulva-sizer operates without dust, easy to clean, ultrafine grinding insured, complete unit of alloy construction. Com-Bin feeders designed to make feeding of damp, oily, difficult-to-feed materials continuous. Pilot rental units available. Both used in processing, pharmaceutical, food, other industries.

EQUIPMENT

70 **PVC Blowers.** Blowers of Boltaron 622 nonplasticized polyvinyl chloride for use in expelling fumes & gases, corrosive air. Field tests show no corrosion or adverse effect after several months under extreme conditions. Impeller blade fabricated of plastic with thread spinner cap aerodynamically balanced for smooth, vibration-free, high-speed operation. Backcurved blade prevents overload & reduces turbulence. Capacities 500, 1,500 & 4,300 cu.ft./min. Bulletin from Industrial Plastic Fabricators, Inc.

71 **Electric Motors.** U. S. Electrical Motors, Inc. announce type H Uniclosed motor. Said to include many revolutionary features such as dripproof design. Splashproof protection. Frame is solid, one-piece cast iron, stator is prewound. Frame sizes 182-184. Lubriflush bearing lubrication provides for new grease for old without disassembly. Air intake designed to avoid pickup of dirt & dust from floor.

72 **Tubing Steel Data Card.** From Babcock & Wilcox Co. an alloy steel tubing steel used in elevated temperature service. TDC 151 discusses Croloy 9M (8 to 10% chromium, 1% molybdenum). Widely used in petroleum conversion equipment. Corrosion data indicate tube life of 40,000 to 100,000 stream hours. Used widely at 1200° F. Included are data on mechanical & physical properties, bending, welding & heat treatment.

73 **Unit Air Conditioner.** For use in industrial control areas where heat, dirt, or fumes create hazardous conditions, the pulpit air conditioner from Dravo Corp. is described in illustrated folder. Condenser & evaporator may be combined with controls in such a way that unlimited capacity ranges are available. Need for duct work eliminated. Sizes 5 & 7½ ton.

74 **Small Control Drive.** Gas & liquid flow regulation are improved by use of small pneumatically operated control drive. Butterfly valves, dampers, feeders, etc., may now be operated on straight-line flow characteristic. Compact & may be installed in any position on column, pipe, or flat surface. From Bailey Meter Co.

75 **Exhaust Fans.** Duriron Co., Inc. introduces complete line of corrosion resisting exhaust fans. Feature all metal resistance to corrosive fumes & gases. Casing is Duriron, rotor is multi-blade, forward curved design of Durimet 20, a high nickel stainless steel. Capacities to 8,000 cu.ft./min. 40% lighter than former Duriron fans.

(Continued on page 58)

"NATIONAL" PROVIDES THE *Economical Solution* TO *Any Drying Problem!*

No matter what your product may be, it can be dried or otherwise processed at a lower cost per pound or other unit, in one or more of the various types of "NATIONAL" equipment.

High-speed production; maximum effective use of the drying medium under finely adjusted control; adaptability to existing plant conditions and future expansion; and the assurance of long, trouble-free operation are among the important reasons why "NATIONAL" machines are being erected in more and more chemical plants throughout the United States and in other countries.

NEW "P-4" CONSTRUCTION:

The result of a radically new approach to simplified Dryer construction, "P-4" Construction provides a precision-built, prefabricated structure, with trussed-and-tensioned insulated panels. It assures a more rigid, durable machine, with installation time in your plant reduced as much as 50%.

"ADD-A-UNIT" DESIGN

This unique accomplishment of "NATIONAL" engineering provides alternatives which are both practical and economical—(1) simplification of the initial installation based on present requirements; (2) maximum adaptability to step-by-step future expansion.

OTHER SPECIAL FEATURES

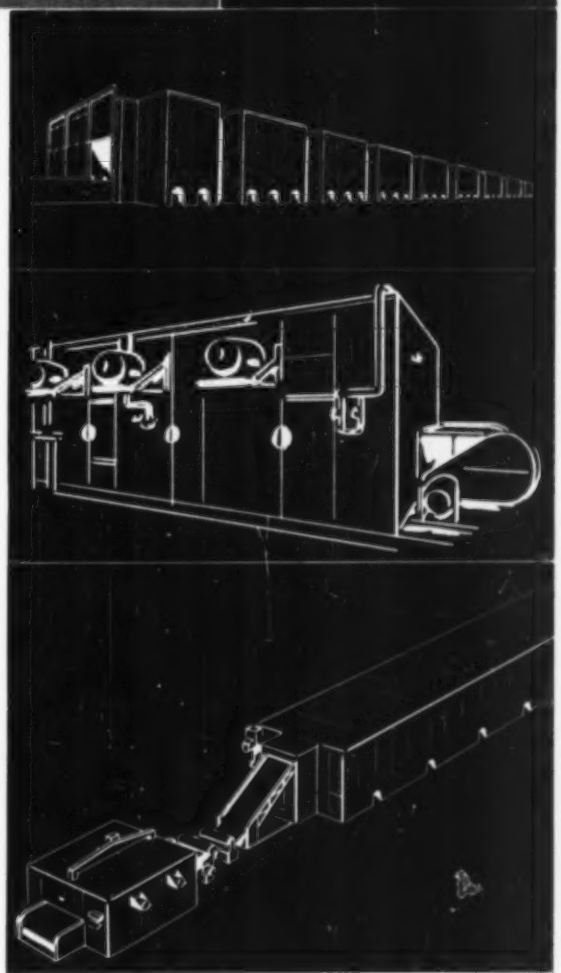
Patented Super-Power Fans, made in our own shops to specifications developed through years of industrial drying experience.

Patented Indexing Orifices, Turning Vanes and other devices and arrangements assure unequalled versatility and precision in air distribution and control.

The heat source may be steam, gas, oil or other medium. "NATIONAL'S" special gas firing systems, *Factory Mutual approved*, provide controlled uniformity of high temperatures; absolute safety; and lower maintenance costs.

• • •

When you have a *new* product which presents a drying problem, or if you want to improve your present drying processes, call "NATIONAL" Engineers for consultation. It is your surest way to improved production and lower over-all costs.



Illustrated above are typical "NATIONAL" Dryers for the Chemical Industry. From top to bottom: Cross-circulation type Truck Dryer; large multiple-unit Tunnel Dryer; single-apron Conveyor Dryer; large multiple-unit Tunnel Conveyor Dryer.

THE NATIONAL DRYING MACHINERY CO.
LEHIGH AVENUE and HANCOCK STREET
PHILADELPHIA 33, PENNA.

76 Centrifugal Clutch Coupling. Added to line of Hilliard Corp. is the Twiflex automatic centrifugal clutch coupling, manufacture of which is licensed by Compression Ignition Ltd. of England. Exceptional ability to handle misalignment; made in many sizes & several types. Improves starting conditions & provides smooth acceleration on drives for high inertia equipment such as mills, mixers, pulverizers, etc.

77 Thermocouple Gland. Developed by Conax Corp. a thermocouple gland incorporating butt welded thermocouple covered by a thin-walled Teflon tube for protection against corrosion. For pressures to 5,000 lb./sq.in. & temperatures from −90° F. to +500° F. Constructed entirely of 300 stainless steel.

78 Gas Measure. Titled "Measuring High Purity Gases," bulletin from Arnold O. Beckman on reliable instrument & sampling system for continuous measurement of high purity gas streams. Assuracy ±0.015% O_2 on full scale range. Being used continuously for checking oxygen in hydrogen, ethylene, nitrogen, argon & other gas streams.

79 Full Encirclement Saddle. Recently developed by Tube Turns, division of National Cylinder Gas Co. a full encirclement saddle is employed in hot tapping of petroleum piping when branch connections must be installed. Provides 360° reinforcement desired when working under high pressures & large diameter pipe & tape. Available in special & standard sizes through 42 in. & in all straight & standard reducing outlet sizes.

80 Sterling Brine Buttons. For speedy regeneration of water softeners & packed in new calibrated bags are sterling brine buttons from International Salt Co., Inc. made of high quality evaporated salt. Calibrated markings on 25- & 100-lb. bags. Do not cake in water softening equipment. Size, shape & density of buttons assures uniform rate of dissolution.

81 Water Demineralizer. Bulletin from Barnstead Still & Sterilizer Co. on new pressure bantam water demineralizer. Delivers demineralized water under pressure so it may be piped to point where mineral-free water is used. Employs renewable cartridge containing ion-exchange resins, which is easily replaceable.

82 Titanium-Base Alloy Sheet. Now available as a production item, weldable high-strength titanium-base alloy sheet, Rem-Cur A-110AT contains 5% aluminum & 2½% tin. Responds to techniques used for commercially pure titanium. Ductility of fusion welded joints reported excellent. Minimum tensile strength at room temperature of 115,000 lb./sq.in. with good maintenance at elevated temperatures. Thicknesses of sheet to .025 in. in addition to previously available plates, bars, forging billets.

83 Centrifugal Pumps. Designed specially for handling corrosive liquids & slurries are centrifugal pumps from Gould Pumps, Inc. Available with entire fluid end in 316, Gould-A-Loy 20, 304 stainless steel, iron, or bronze. Maximum liquid temperature limitation for pump operation 350° F. Single or double mechanical seals.

84 Solenoid Valve. A solenoid valve of stainless steel for high pressures available in ½ to 1½ in. pipe sizes available from Atkomatic Valve Co. ½ & ¾ in. sizes rated to 2,500 lb./sq.in.; 1½ in. to 3,000 lb./sq.in. Piston rings compensate for expansion under heat & eliminate sticking. Explosion-proof housings optional in hazardous atmospheres.

85 Tapered Gear Pump. For extra duty in tough applications tapered gear pump from East Shore Machine Products Co. Developed to handle liquids containing abrasive material or foreign matter normally wearing on gear pumps. Impeller gears ground with 2° taper after hardening to match tapered recess in housing. Nominal capacity 8 gal./min. will deliver to 18 gal. at 1,000 rev./min. at pressures to 250 lb./sq.in.

86 Seal-Balanced Angle Valve. Hammel-Dahl Co. seal-balanced angle valves give balanced control at high pressure differentials with tight shutoff. Embody advantages of Venturiflo design. Sizes 1 to 8 in.; body ratings 150 to 1,500 lb. ASA standard at temperature of 450° F. Shutoff attained by sealing pressure in body bowl from balance chamber with exclusive Dahl seal.

87 Liquid Level Transmitter. Minneapolis-Honeywell Brown Instruments Division announce a differential converter transmitter model 292N1, for measurement of liquid level in closed tanks under pressure or vacuum. Said to be highly responsive, fast & accurate. Do not use mercury, are small, easily installed. Adjustable range 0 to 14 & 0 to 200 in. of water. Bulletin includes other pertinent data.

88 Infrared Analyzer. Unique multi-component infrared analyzer developed by Perkin-Elmer Corp. automatically performs complex chemical analyses at push of button. Primarily for use in continuous processes. Applicable wherever need exists for conducting many routine analyses of more than a single component or mixture. Data presented ready for automatic computing.

89 Ultrasonic Energy Generator. Wide-range 400 watt ultrasonic energy generator announced by Rich-Roth Laboratories. Embodies variety of transducers for production line or laboratory degreasing, emulsifying & dispersing. Operates over range from 10 to 1,200 kc./sec.

90 Mag/Nu/Matic Transmitters. For use with all types of pneumatic receivers and/or control instruments Mag/Nu/Matic transmitters from Brooks Rotameter Co. Only three moving parts, improved dynamic response time, positive float position pickup, lightweight, compact. Illustrated folder explains operation, other details.

91 Distillation Apparatus. Two new high vacuum molecular stills are announced by Bronwill Scientific, Inc. Two types, cyclic & pot. For distillation of liquids & solids with molecular weight of 250 or 700. Both models are portable, easily operated for laboratory use.

92 Zirconium. "Facts About Zirconium," a concise compilation of information about its history & production. Also facts about physical properties, chemical properties, fabrication including melting, forging. Chapter on zirconium chemicals. The Carborundum Co.

93 Power Relay. Described by the Swartwout Co. as Autronic type P2R power relay an electropneumatic transducer designed to operate with their control system. Takes output from controller, converts it into air-loading pressure proportional to electric current. Utilization of low cost & flexible air-operated valves is made possible without transmission lag usually encountered in all-pneumatic sysems. No electric motors, boosters or slide wires. Can be made explosion-proof.

94 Firetube Steam Generator. Said to be smallest 250 hp. firetube steam generator ever put into production. Developed by Cyclotherm division U. S. Radiator Corp. Length only 9 ft. 5 in. Increases power in outgrown boiler rooms as much as four times. Also in marine installations.

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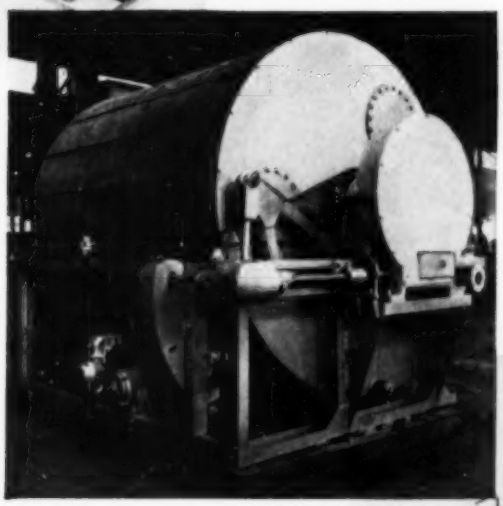
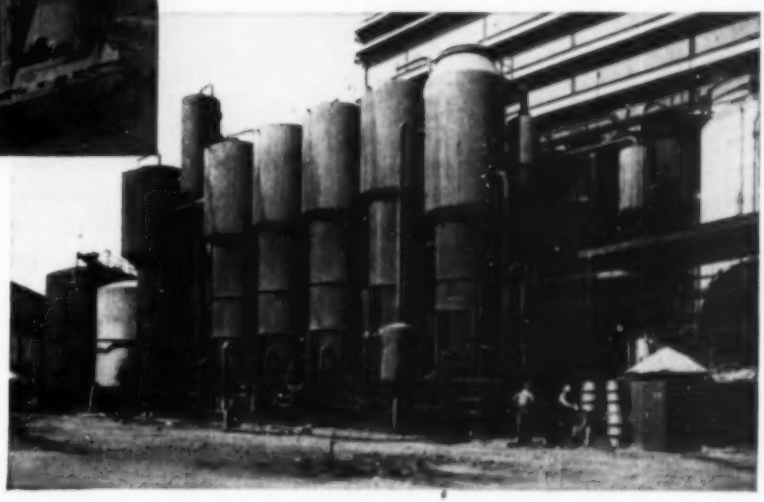
designed and built for optimum performance

Conkey filters, evaporators and crystallizers are now being fabricated in CB&I's four strategically located plants. Each unit is specifically designed by Conkey engineers and built by CB&I to the specified requirements.

If you have a filtering, evaporating or crystallizer problem contact our nearest office. For many years Conkey engineers have successfully solved many such problems for process plants and will be pleased to assist you.





Top: Vacuum Crystallizer

Center: Rotary Drum Vacuum Filter

Right: Sextuple Effect Vacuum Evaporators

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Chicago 4 ..... 2136 McCormick Bldg.	Pittsburgh 19 ..... 3207 Alcoa Bldg.
Cleveland 15 ..... 2232 Midland Bldg.	Salt Lake City 4, 560 West 17th South St.
Detroit 26 ..... 1546 Lafayette Bldg.	San Francisco 4 ..... 1536—200 Bush St.
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Only Brown flow meters offer you these profitable "*plus*" *values*

- ***16 different types*** of basic instrument systems . . . a flow meter for every fluid, every pressure, every operating requirement. *You're sure to find the most profitable meter for your specific application.*

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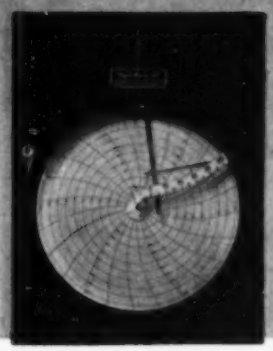
- ***Nationwide field organization.*** Brown flow metering consultation is available from experts in more than 90 field offices, located near every major production center. *You're sure to have application engineering on hand where and when you need it.*



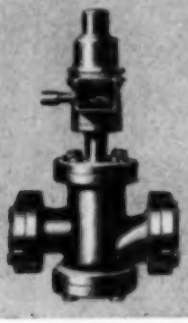
Linear scale meters—mechanical or electrical types, all control forms.

Square root scale meters—mechanical, or electrical or pneumatic transmission . . . all control forms.

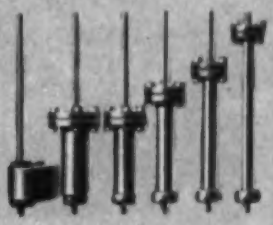
Portable meters—versatility, for spot checks of flow values not continuously recorded.

Low pressure meters—either electrical or mechanical type, for air or gas flow.

Differential Converter—mercury-less pneumatic flow transmitter with infinitely adjustable range.



Area Type Meters for measuring flow of viscous fluids . . . electrical transmission.



Interchangeable range tubes typify rangeability of all Brown flow meters.

NOTE:

Tel-O-Set miniature instruments and *ElectroniK* indicators, recorders and controllers are available for use with all flow transmitters.

a flow meter for every fluid...

every application (all available with electronic integration)

In performance, too, Brown flow meters provide you unsurpassed precision . . . reliability . . . convenience . . . with minimum maintenance requirements. In every way, you'll find it pays to select your flow meters from the one line that offers the most value.

Your nearby Honeywell sales engineer will be glad to discuss your specific flow application . . . and he's as near as your phone.

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● **REFERENCE DATA: Write for new Catalog 2320, "Flow Meters, Indicating, Recording, Integrating, Controlling."**

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352 BABCOCK STREET, BUFFALO 10, NEW YORK

A Chemical Engineer in Spain

(Continued from page 36)

Invitation cards were issued. Just before the lecture to be held in the lecture hall of the University, I was taken to the office of the Rector (equivalent to President of an American university) where were assembled the Rector, Dean, American Consul, Vice Consul, and several members of the faculty. We marched in a solemn procession down the center of the hall, as the audience—nearly 300 of them—rose and stood until we took our seats on the dais. After a brief but somewhat flowery introduction I was launched. I had been carefully schooled by Professor Calvet in the proper type of salutation prescribed for such occasions, which is so typically Spanish—beginning with "Magnifico Rector, etc."

Magnifico Audiences

Although the subsequent twenty-three lectures were held in a smaller and less pretentious classroom, still an amazingly large audience made its appearance each time. At the first lectures in the smaller room there were anywhere from 150 to 200 people with many standees, and even at the end of the series never fewer than 100 were in the audience. At the end of each lecture various members of the chemistry faculty congratulated me warmly and expressed their satisfaction and pleasure. I mention this in appreciation of the courtesy and warmth of the Spanish people.

An outline of the subject matter of the lectures follows.

Subject	No. of Lectures
Profession of chemical engineering	1
Education of a chemical engineer	1
Basic concepts, principles and methods of calculation	2
Material balances	2
Applications of thermodynamics to chemical engineering	4
Fluid flow	4
Heat transfer	5
Unit operations based on phase distribution	
(a) Single-stage operations	2
(b) Multistage operations	3
Total	24

The lectures, after the first two, were illustrated by problems and diagrams of equipment. Solutions to the problems naturally required the presentaton of many numericals, figures, and graphs, and it was my practice, as a time-saver, to spend about an hour before each lecture putting this material on the blackboard. In some cases I also took various exhibits to be examined after the

(Continued on page 64)

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Whatever filtration problem you face, it will pay you to investigate the Celite Filtration method now. A Johns-Manville Celite Filtration Engineer will gladly discuss your problem. For his services, without obligation, write Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay St., Toronto 1, Ontario.

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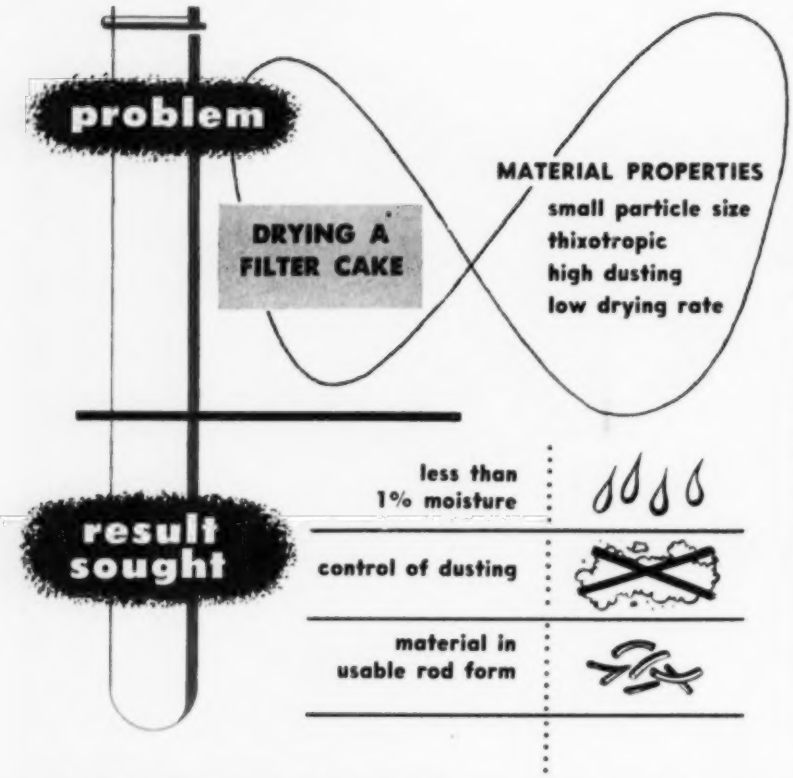

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To overcome the highly undesirable high-dusting quality of the material, a change in drying method alone was not the answer. Sargent engineers analyzed the pre-drying conditions — first in the field, then in the Sargent Drying Research Laboratory.

Result of this research was a special extruder, designed and built by Sargent, to form the material into anti-dusting rods with a high drying rate, and the anti-dusting quality maintained throughout the drying cycle.

Extensive drying tests in the laboratory explored every possible variable — temperature, air flow, maximum practical material bed thickness, etc. The span of high efficiency of each variable was bracketed.

In the dryer as designed, each variable could be adjusted as desired, within the bracketed span — a factor of great importance in this particular process. In production for several months, the Sargent Dryer is producing consistently, steadily, efficiently . . .

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A Chemical Engineer in Spain

(Continued from page 62)

lecture. My natural inclination was to carry these myself to the classroom from the office placed at my disposal, but I soon learned that in Spain it is beneath the dignity of a professor to perform so menial a task, including erasing from the blackboard. These things are done by a species of servant known as a "bedel." In fact throughout our stay in Spain, Mrs. Dodge and I found it difficult to perform for ourselves many little tasks, such as opening doors, starting elevators, carrying packages, and lighting cigarets. If there was a servant available, he or she would hasten to perform these operations. It got to be a sort of game to see if we could beat the servant to the job.

At first in giving the lectures I had to stay very close to my manuscript and no deviation was possible even when pointing to the material on the board. Gradually as my facility in the language improved, I could manage a few small departures from the manuscript and toward the end I could even leave the manuscript on the lectern and go off to the board and explain a graph or set of figures without reference to the written word. Occasionally I found it necessary to call for assistance from Professor Calvet, who was always present in the front row. I endeavored to encourage questions from the audience but was never very successful, as it apparently is not the practice in Spain to ask many questions of the professor.

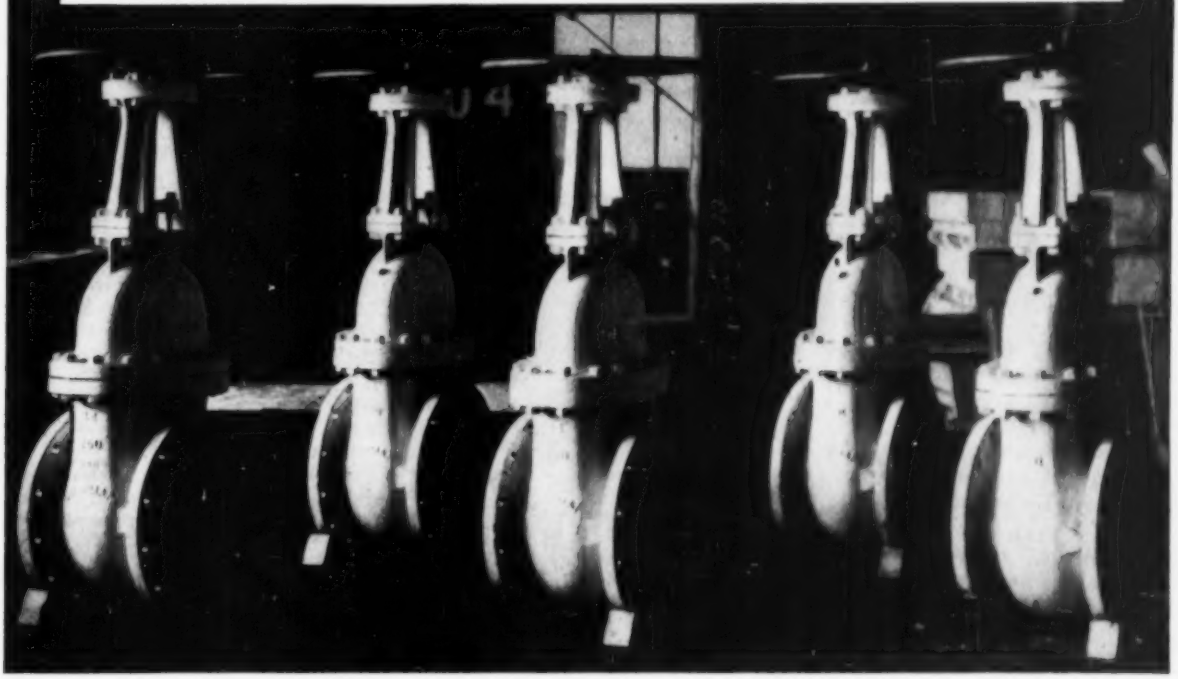
The amount of publicity given to my lectures in the Barcelona newspaper, La Vanguardia, was surprising to me. Several fairly long accounts of the lectures appeared, and on one occasion I was interviewed by a columnist who also drew a caricature of me which appeared with his article. When he learned that I had worked on the atom bomb at Oak Ridge, he directed most of his questions along this line. This did not please the Spanish censor and much of this material was deleted from the article!

Chemical Engineering in Europe

As stated previously chemical engineering, as a distinct branch of engineering, is little known in Europe; it is almost entirely an American development. In both France and Spain, engineering is not a recognized faculty of a university; hence there was no engineering officially taught at the University of Barcelona. Engineering is taught at separate engineering schools, of which there are only three in Spain. The course is of six-years' duration, and

(Continued on page 66)

Approximately 500 Gate Valves similar to these cast in 2.50/3.00% nickel steel for -150°F. service were recently shipped to a large chemical company by Chapman Valve Mfg. Co., Indian Orchard, Mass. Ranging from 2" to 20" sizes in the 150, 300, 600 and 900 lb. series, and made to ASA B16 5-1953 specifications, this order required the melting of 500,000 lbs. of steel.



Why these valves stay strong at -150° F

Carbon steels and many alloy steels become brittle at low temperatures.

The addition of nickel, however, increases resistance of steel to sub-zero embrittlement. That's why Chapman Valve Manufacturing Company regularly uses nickel steel for valves intended for low temperature service.

Chapman produced the group of valves, shown above, in low carbon 2.50/3.00% nickel steel, to assure adequate toughness under operating temperatures of -150°F.

Tests of seven heats of this steel provided the following average mechanical properties, after double normalizing and tempering:

Tensile Strength, p.s.i.	80,900
Yield Strength, p.s.i.	48,600
Brinell Hardness	153
Elongation in 2" %	30.3
Reduction of Area %	52.7
Charpy Impact, (Keyhole) ft. lbs. at -150°F.	32.9

This exemplifies the way ample toughness for sub-zero service . . . as well as strength and toughness at normal temperatures . . . can be assured by using suitable nickel steels.

Whatever the temperatures of your operations, consult us on the use of nickel alloy steels, nickel alloy irons or other alloys containing nickel in your equipment. Send us details of your problems for our suggestions . . . write today.

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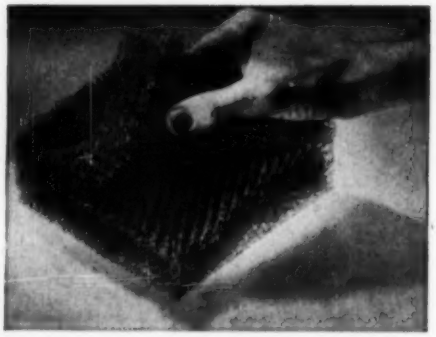
IF SO

GET THE FACTS ON METEX MIST ELIMINATORS!

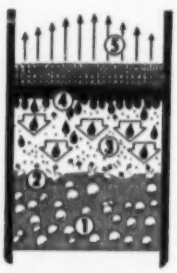


Section of a METEX MIST ELIMINATOR, opened to show construction. Factory cut to fit vessel dimensions and contour, there is no limit to the size in which they can be obtained. They can be made of practically any metal, to combat corrosion.

These separators, which are made from layers of knitted wire mesh, literally "filter out" the liquid droplets by impingement and accumulation in depth (see diagram). The liquid is returned by gravity: The gas passes on freed from the unwanted—and often contaminating entrainment.

METEX MIST ELIMINATORS can be easily installed in new or existing vessels. Special housings are not needed, and they have no moving parts to require power and servicing. They will function over an unusually wide range of velocities with a pressure drop generally well under 1" of water. Efficiencies of 99% and over are commonly reported.

While liquid entrainment is an inevitable result of practically any processing operation involving the handling of liquids and gases together, it need no longer be considered as an unavoidable evil. It can be controlled simply, effectively and economically – by a Metex Mist Eliminator, as more and more engineers are finding from experience.



When a gas is generated in or passes through a liquid (1) it carries with it on leaving the surface (2) droplets of entrained liquid. These droplets are carried upward by the rising gas stream (3). As the gas continually changes direction in passing through the pad, the droplets are impinged on the extensive wire surface. Here the droplets coalesce, forming large drops of liquid which break away (4) from the pad and fall back through the gas stream. The gas (5) passes on, freed from liquid entrainment.

Write TODAY for free catalog giving complete information and engineering data. Or tell us about your SPECIFIC entrainment problem.

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METEX

Roselle, New Jersey

A Chemical Engineer in Spain

(Continued from page 64)

I was told that the competition for entrance was so keen that many candidates spend as many as two years in a review of basic sciences as a preparation for the examinations.

The first three years are devoted to basic engineering sciences common to all engineering and there are no options. In the fourth and fifth years there are four optional groups which permit some specialization along mechanical, electrical, civil, and even chemical lines. The latter, however, does not involve much chemical engineering as we understand it but is more in the nature of industrial chemistry. The graduates of these schools are known as industrial engineers. I visited the engineering school in Barcelona and was favorably impressed by the content of the course and by the exhibits of the students' work. As in the University of Barcelona, the laboratory equipment, with a few exceptions, was meager and antiquated.

Professor Calvet has managed to introduce quite a little chemical engineering into his course in Quimica Tecnica (Technical Chemistry). In fact he covers a large part of the material in Badger and McCabe and gives a few problems. In the second semester of the course the students are assigned process design projects. I examined a number of these and found them about equal to what an undergraduate in this country would produce. Of course there are no laboratory facilities whatever for chemical engineering anywhere in Spain. Surprisingly enough, however, there is a recent text book "Elementos de Ingenieria Quimica" by Ocon and Vian, which I regard as a good undergraduate text and quite the equal of anything that we have in this country.

All education in Spain (also true in France) is under state control and all professors are government employees. The only exception to this that I am aware of in higher education is a School of Chemistry, which is owned and operated by the Jesuits in Barcelona. I visited this institution, and, although it has rather poor library and laboratory facilities and is supported entirely by the tuition payments, I got the impression that a creditable job was being done. The professor of technical chemistry was certainly an intelligent person, well versed in his field.

On my way to Spain I spent a day at Toulouse, France, where I put in a semester in 1951 as a Fulbright visiting professor. This is one of the two centers in France where chemical engineering is being developed (Nancy is the other) and I was pleased to observe that

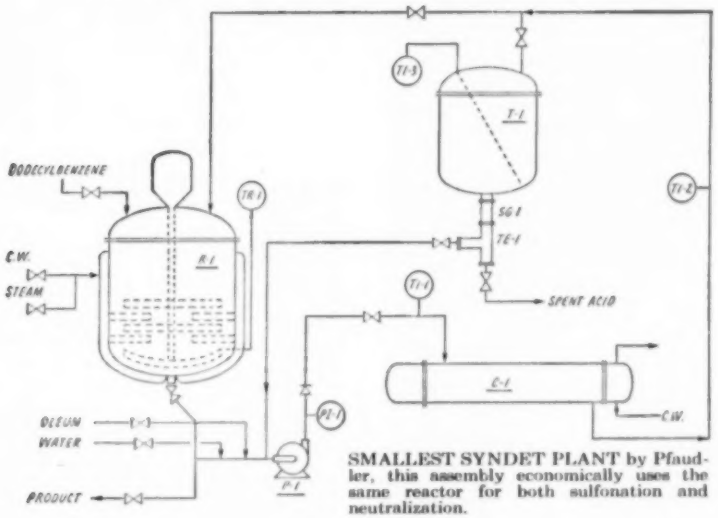
(Continued on page 68)

Corrosioneering News

Quick facts about the services and equipment Pfaudler offers to help you reduce corrosion and processing cost.

Published by The Pfaudler Co., Rochester, N. Y.

Junior-Sized Synthetic Detergent Plant Permits Experimental or Small-Scale Production



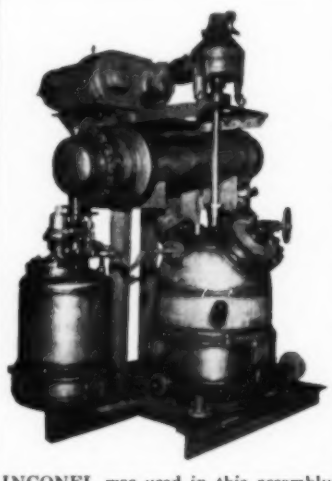
SMALLEST SYNDET PLANT by Pfaudler, this assembly economically uses the same reactor for both sulfonation and neutralization.

To meet the growing demand for a small-scale alkyl aryl detergent plant, Pfaudler now offers a complete pilot plant, priced less than $8,000.

You get every basic part, including piping, fittings, and instruments. No welding is required on the piping.

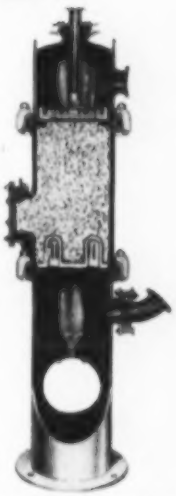
All items are glassed or stainless steel. This system will produce up to 400 lbs. of finished detergent slurry in an 8-10 hour day. With the addition of a second reactor, semi-works production is possible, producing about 2,000 lbs. of high active detergent slurry in a 24-hour operating day.

Many plants are now saving money by producing their own detergent. Perhaps this low-cost "all-in-one" plant is the most convenient way for you to begin this practice. Write us today for further details.



INCONEL was used in this assembly for solvent recovery. See article (right).

First Column Ever To Have a Family!



They said it couldn't be done. They said every glassed steel column had to be a custom job, built to meet the customer's special requirements.

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For more information about *standard* glassed steel columns, write us today.

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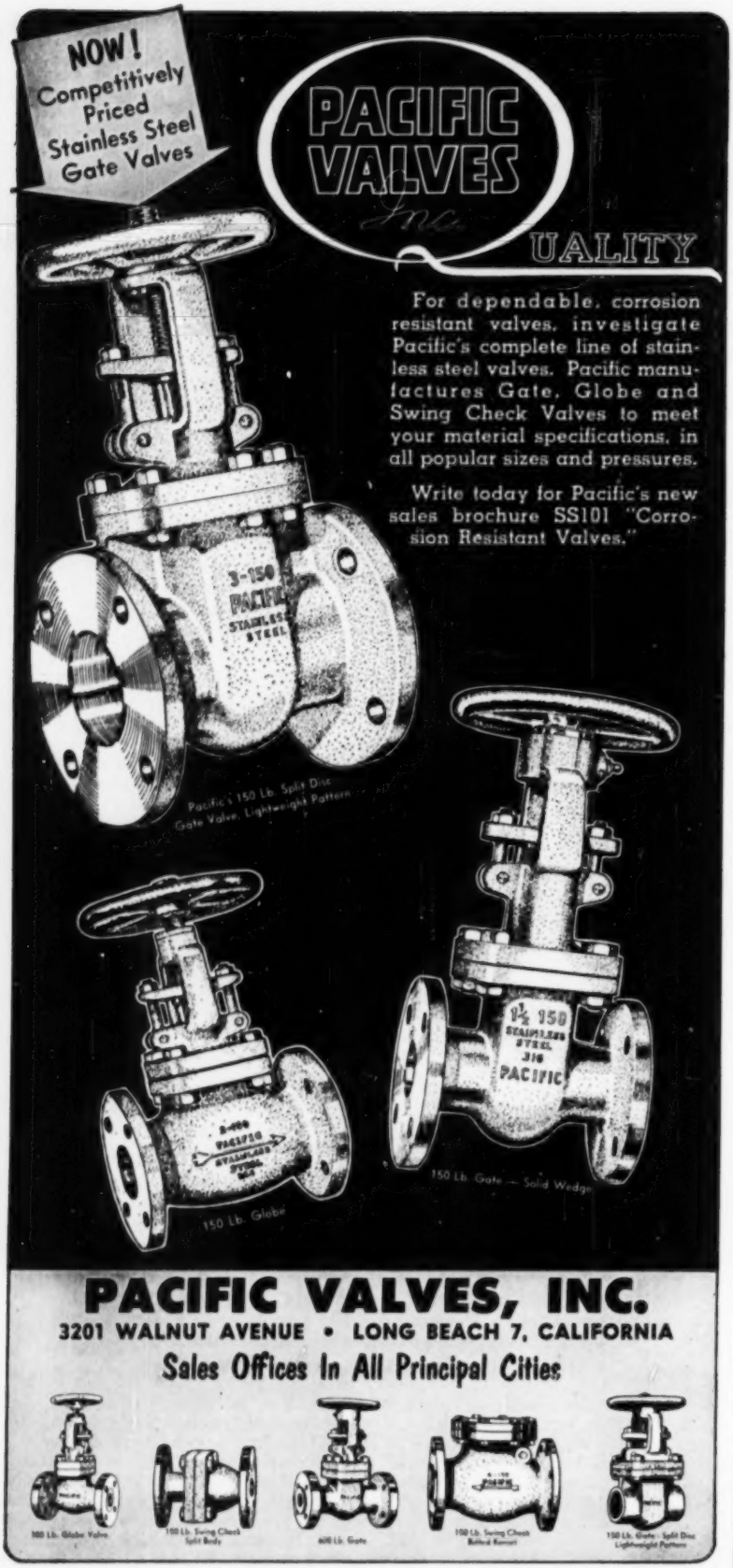
Hastelloy, monel, nickel, inconel, aluminum, titanium—through experience with hundreds of corrosion applications, Pfaudler knows just which alloy will best suit each situation. You can be sure of exactly the material of construction that will do the job best, because Pfaudler has no "favorite sons."

If you've a process equipment problem involving corrosion, contact your Pfaudler representative for an unbiased analysis of your needs or drop us a line today.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A Chemical Engineer in Spain

(Continued from page 66)

they had progressed to the point of building several very good laboratory setups for the study of unit operations.

Donkey as Prime Mover

Industrially and mechanically Spain is a backward country. As we traveled about, we were struck by the primitive methods for many operations. For example, very little road-building machinery is used. The work is all done by manual labor and the dirt is conveyed away to the dump in bags on the back of donkeys. One meets up with these donkeys everywhere since they are used for all kinds of transport in the country and even in the cities. The donkey became a sort of symbol of Spain to us and Mrs. Dodge coined the apt phrase "the donkey economy."

Dictatorship

Often asked about evidences of the dictatorship in Spain, we can say that actually we were hardly aware of it. We did notice that none of our friends were inclined to discuss political questions. Our most direct contact with politics was our occasional inability to buy certain issues of either the New York Herald Tribune (Paris edition) or a British or French newspaper. This happened about once a month and the only explanation we could get was that they had been banned by the censor. I met a physicist who had formerly been a university professor but who had been somewhat active on the "wrong" side in the civil war and has never been able to obtain another university or any teaching post.

Life in Spain

The standard of living in Spain is very low, especially in the south. In certain places we saw hundreds of people living in caves cut into the hillsides. Fuel is scarce, and everything combustible, even nut shells, is carefully saved for fuel purposes. The pay of university professors is pitifully low. The highest grade of professor receives about the equivalent of $120 a month. Even allowing for the relatively low cost of living in Spain, this is far below our standards and considerably below the prevailing rates in France. We marveled at the way my colleagues at the University were able to manage on this small salary. Of course they do not have automobiles and many of the other mechanical devices that we consider necessities.

German Plants and Know-How

The chemical industry is not well developed in Spain. I did not have the time to visit many plants though Barcelona is in the center of the leading industrial area of Spain. I did visit two fairly large plants, one devoted to manufacture of phosphate fertilizer and other inorganic products, and the other to organic products, such as dye intermediates, pharmaceuticals and insecticides. One of these plants was fairly modern but there was less use of instrumentation and automatic control than in an equivalent plant in the U.S.A. Little research was done at either plant and in fact one of them was just starting a research laboratory. I believe that this is typical of all chemical industry in Spain. Most of the equipment and the "know-how" for these plants were imported from Germany.

One of the Spanish customs that most Americans have trouble adjusting to is the late dinner hour. The restaurants do not even open till 9:00 P.M. and about 10 P.M. is the customary hour. All business in the towns and cities practically ceases from 1 to 4 in the afternoon and all the shops are closed. Then from about 5 to 7 P.M. it seems as though everyone piled out into the streets, so difficult is it to elbow one's way through the throngs. On late Sunday afternoon everyone goes out for a walk on a nice day and it becomes almost impossible to drive a car through the narrow streets of an old city like Segovia because everyone walks in the street and pays little attention to cars.

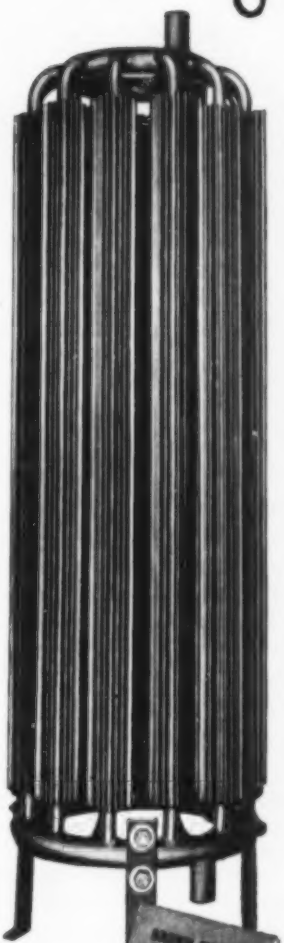
There are many other interesting observations that could be made about life in Spain but these few will serve to give a little idea of an interesting country that Americans are just beginning to discover. We enjoyed our brief stay very much and are looking forward to the time when we can return.

Adios. Hasta la Vista!

Illustrations courtesy Spanish State Tourist Office.

4 reasons why

BROWN FINTUBE TF-18 TANK HEATERS HAVE OBSOLETED OLD FASHIONED TANK COILS



1) **LOWER COST**—Users report that the cost of TF Heaters plus their installation is usually less than the cost of just installing bare pipe coils of equivalent capacity.

2) **VERTICAL MOUNTING**—on legs about 10" above the tank floor brings the entire heating surface in contact with the tank contents—avoids heating through a layer of sediment.

3) **MUCH INCREASED EFFICIENCY**—Finned construction provides approximately 7 times more heating surface per foot of tube length than plain bare pipe—permits more heat to be transferred—faster—at lower temperatures per square foot of surface, avoiding coking or damage to heat sensitive products.

4) **EASY INSTALLATION**—TF-18 heaters pass easily through a standard manhole permitting installation in new or existing tanks. They do not require welding inside the tank. Manifolded into groups or individually trapped.

You can't keep your operations competitive with old fashioned, obsolete methods. Write today. Get full details about these new, fully proved, less costly, more efficient tank heaters.

New fully descriptive Bulletin No. 541 gives dimensions and full details. Write for your copy today.

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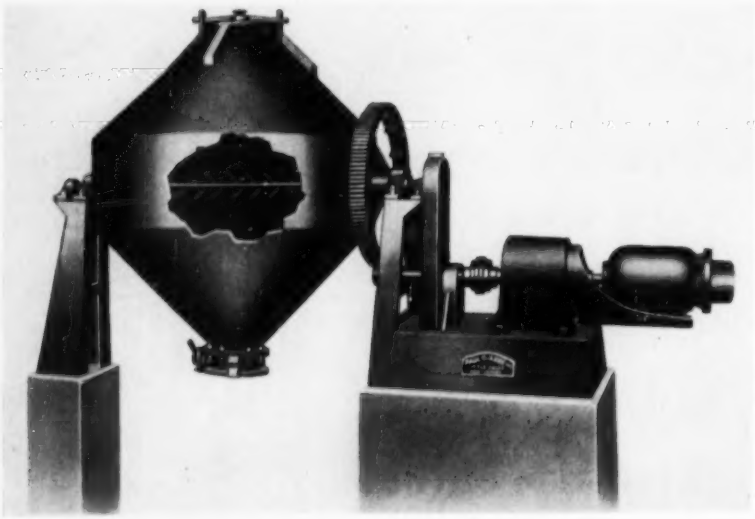
FRIEDRICH UHDE, GMBH, DORTMUND, GERMANY

Beating Element in Double Cone Blender

Assures Peak Performance



Paul O. Abbé Double Cone Blenders have long been noted for giving thorough, rapid action in the mixing of dyestuffs, and industrial chemicals, pharmaceuticals, food stuffs and many other products.

Mixing is rapid and exceptionally thorough, regardless of the number and comparative weights of different materials in a batch.

This speed and thoroughness can now be further enhanced by the addition of a Beating Element which has been thoroughly proved, under plant operating conditions.

This beating element, which operates through a separate drive, breaks up lumps and prevents re-aggregation of the particles. It, consequently, assures a more rapid and thorough blend. The entire element is readily removed for cleaning.

The number and length of the pins, and the speed can be varied to suit the material mixed.

Paul O. Abbé Double Cone Blenders are furnished with gear motor, silent chain, V-belt drive or pulley drives. Magnetic brakes can also be supplied for spotting and inching.

These blenders are made of Steel, Stainless, Monel, Aluminum, Bronze or other metals.

Write today for descriptive literature.

PAUL O. ABBE

271 Center Avenue **Little Falls, New Jersey**

PUMP FEATURES ELEVATED STUFFING BOX

(*Continued from page* 35)

never be permitted to reach the top of the stuffing box in the sump cover. The active end of the pump, reaching to the bottom of the sump, is submerged. A transfer pipe reaches from the reactor to the sump and a vent from the top of the sump to the reactor equalizes the pressure in the two vessels.

A vertical shaft pump in such an arrangement has much to commend it, and in this case as in many others where we have applied this arrangement, the problem of stuffing box losses is completely eliminated. The factor of submergence of the bearing is critical, however, and would inevitably result in frequent bearing replacements which could become a nuisance and expense offsetting the other benefits. For that reason, a cantilever shaft design with the bearings outside the sump and no rubbing contact between the revolving and stationary parts below the seal was employed.

This arrangement places the bearings, coupling, and motor up and away from any possibility of drip, spill, or leakage, and has proved very effective, according to reports. The unit employed in this particular service was a 2 in. Type SW-OB Frame 95J vertical, cantilever shaft Nagle pump, coupled to a 10 HP 1,800 rev./min. motor, and rated at 100 gallons against 80 ft. of head. The sump was 18 in. diameter by 42 in. high, and all parts in contact with the liquid or gases were made of Hastelloy C.

Perry Nagle
Nagle Pumps, Inc.
Chicago Heights, Ill.

AXIAL PUMP HANDLES ACID SOLUTION

(*Continued from page* 35)

terials of construction throughout is *L*-20 alloy, which is equivalent to Carpenter No. 20. Four of these pumps are in use in one west coast plant.

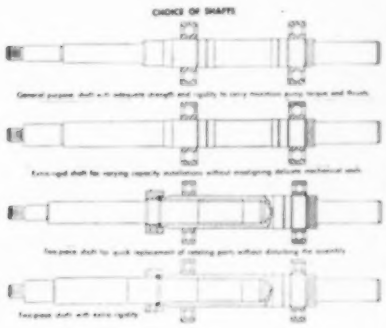
Victor J. Mill
Lawrence Pumps, Inc.
Lawrence, Mass.

NEW FIRM OFFERS NUCLEAR SERVICES

Former Oak Ridge public relations and public information official Gordon R. Molesworth announces the establishment of Molesworth Associates. The new firm will specialize in public relations counseling to industrial firms engaged in nuclear engineering activity. Most recently Mr. Molesworth was the director of the Nuclear Energy Information Division of Bozell & Jacobs, Inc.

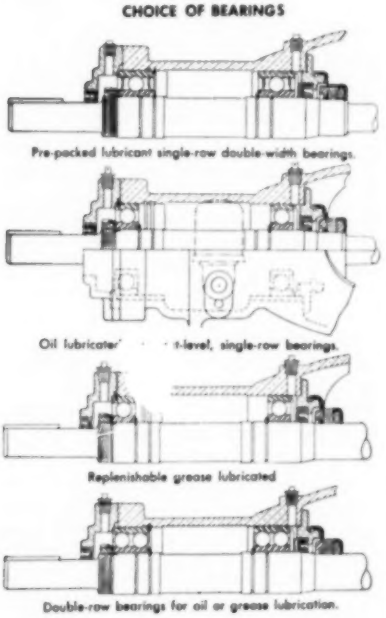
CHEMICAL PUMP FEATURES INTERCHANGEABILITY

(Continued from page 35)



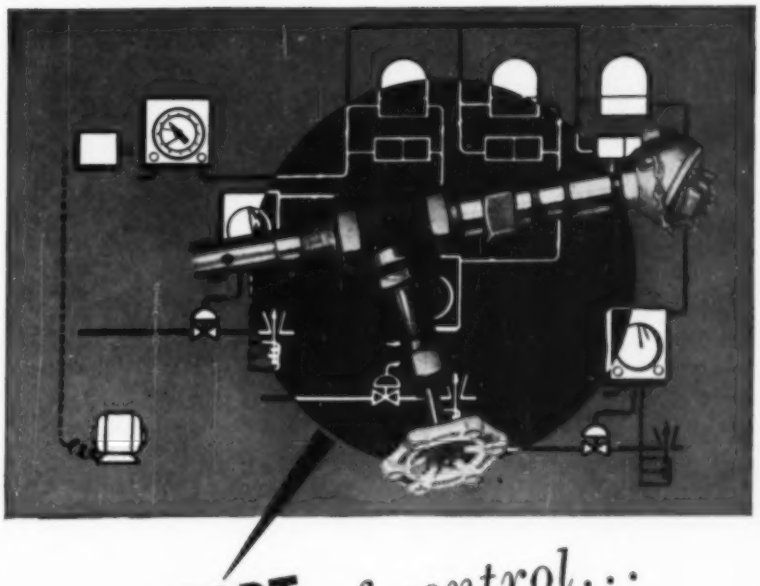
units necessary to be carried in stock by the operator.

The optional and interchangeable features consist of bearings, shafts, shaft seals and impellers. These, with the exception of the impellers, are illustrated by the accompanying line drawings, which include one showing the fixed features which are part of each basic pump.



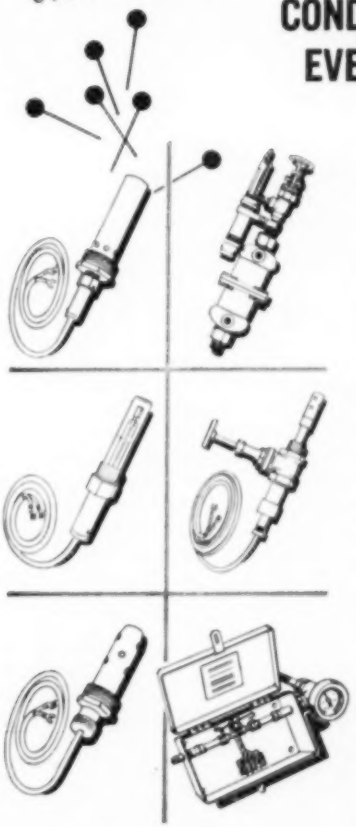
One of the unusual aspects of the development of this line of pumps is the user-research that was undertaken to establish which qualities were most wanted by those experiencing actual pump operating problems. Much of this surveying was directed towards chemical engineers in chemical process plants, who have responsibility for selection, operation and maintenance of pumps.

Stuart C. Lawson
Ampco Metal, Inc., Milwaukee, Wisc.



the **HEART** *of control...*

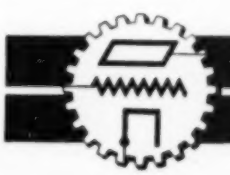
CONDUCTIVITY CELLS FOR EVERY APPLICATION



Positive measurement and control at any point in a process starts with the proper conductivity cell. Temperature range, pressure, nature of solution and operational range of process all enter into the proper selection of the conductivity cell.

Industrial Instruments manufactures a complete line of conductivity cells with models for every application. A wide selection of materials, mechanical designs, and cell constants make it possible for our engineers to recommend the cell that will do the job best. In addition to cells, Industrial Instruments manufactures a complete line of sample coolers, measuring and control instruments. For processes involving temperature fluctuations, automatic temperature compensation is available in the conductivity cells.

WRITE FOR—
Catalog No. 20 which lists complete line of conductivity measuring and control equipment. . . .

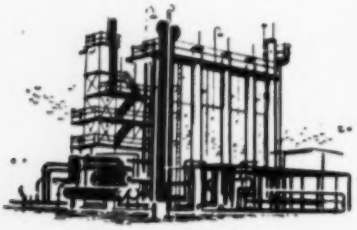


Industrial Instruments

89 COMMERCE ROAD, CEDAR GROVE, N. J.

PROBLEM

To produce hydrogen essentially free of carbon monoxide which has a deleterious effect on product quality and plant capacity for edible oil producers.



SOLUTION

GIRDLER developed a highly active durable catalyst, G-12, for removal of carbon monoxide from the hydrogen. Cost of hydrogen production was reduced and carbon monoxide content was cut 95% resulting in:

Hydrogen with less than 5ppm of carbon monoxide

Take advantage of the experience of Girdler in solving *your* catalyst problems!

FOR

Catalysts

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The

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A DIVISION OF
NATIONAL CYLINDER GAS COMPANY
Gas Processes Division
LOUISVILLE 1, KENTUCKY
NEW YORK • TULSA • SAN FRANCISCO

COMBINATION LOW HEAD PUMP AND MIXER

(Continued from page 35)

between stages of multi-compartment mixer-settler extraction system. Outside piping and interstage pumping was eliminated by using a similar lifter design illustrated by Figure 2, which is based on the Turbo counter-current treater (patented). In this instance, the bottom of the mixing is closed off by a solid horizontal disc attached to the blades. Additional blades of the correct dimension to meet the head requirement are welded to the underside of the plate. The impeller rotates at close clearance to the bottom dish of each compartment having a central orifice for entry of the two phase liquid to the compartment.

The horizontal plate and the dished bottom of the compartment form the pump casing, the disc half being a rotating member. Stator blades are again mounted around the impeller to prevent swirl in the pump and also to act as the swirl controller and mechanical shearing members for the upper mixing half of the impeller. Sufficient head is developed on the effluent stream from the stage, and suction on the influent stream, to produce counter-current flow of the two immiscible liquids through the several mixing and settling stages of the system.

This simple method of converting a mixing impeller into a high capacity, low head pump, was first developed in the early 1930's for a service suggested by the Dorr Company, Inc., for the sanitary field. In a water treatment plant the influent stream passes through a flash mixer in which treating solutions are added, followed by a long flocculating chamber 100 or more feet in length. A head loss develops in the length of the flocculating chamber which must be accounted for in a lowered level of the effluent channel. Plant designs can frequently be simplified if this loss in elevation can be achieved at low cost.

The Turbo Lifter was developed for the purpose of flash mixing and generating a head of two or three feet on the feed water. The effluent channel could then be maintained at the same elevation as the influent. Typical designs for this type of unit are shown in Figure 3. The impeller is completely closed on the top side with the bottom side operating at close clearance to a restricted orifice plate, as mentioned above. Stationary blades around the periphery of the impeller assist in its centrifugal force development.

The slippage factor in the impeller is large compared to ordinary pumping service. However, the few feet of head development required makes this inefficiency important. This design does permit the handling of very large volumes

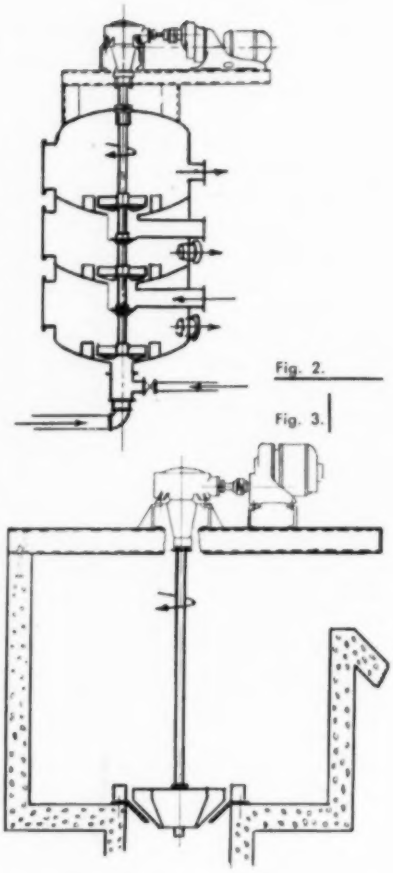


Fig. 2.

Fig. 3.

of liquid at a low head development at a lower power cost. It simplifies the construction of the pump casing and eliminates costly valves and piping. Several variations of the impeller design have been used including the conical "weedless" type and the swirling type for exceedingly large liquid volumes. This latter device takes advantage of the swirling head developed in the flash mixing chamber, in addition to the positive head development in the impeller, to achieve the total head required at least cost.

The same principle is used in forced circulation evaporators and vat type heat exchangers to develop a pressure head on the stream of liquid through the calandria. In this case the throat plate is placed at the bottom of a central draft tube. The impeller is mounted on the underside of the throat plate with its bottom face completely closed.

A large number of Turbo Lifters have been installed in water and sewage treatment plants by the Dorr Company, Inc., over the last twenty years. Many others have been installed in forced circulation heat exchange systems, in large vat recirculation, and similar services.

E. J. Lyons
Turbo-Mixer
Turbo-Mixer Div., G.A.T.X.

HYDRIDE REDUCTION SERVICE ANNOUNCED

Unit processes involving chemical reductions utilizing a metallic hydride as the reducing agent can now be employed by companies that do not have reduction facilities. A new custom reduction service of Metal Hydrides, Inc., of Beverly, Mass., reduces material sent by the customer and returns it for further processing. Companies who do not wish to tie up equipment or who are unfamiliar with the techniques of handling hydride reductions can utilize the expanded facilities of Metal Hydrides as a supplement to their own plant operation. Metal hydrides may be used as reducing agents of organic acids, esters, ketones, aldehydes, or acid chlorides with or without hydrogenation of double bonds.

SUPPLEMENT TO FILM LIST PREPARED

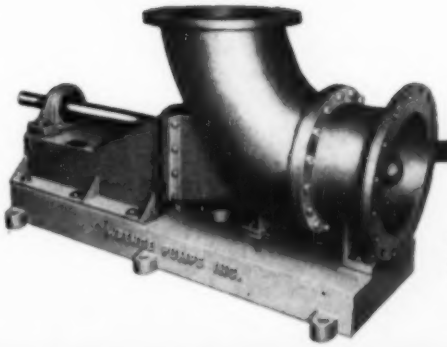
A supplement to the chemical engineering film list originally published in 1953 by the Institute has been prepared by Marriott W. Bredekamp of Michigan College of Mining and Technology. The list, which is a joint effort of the Institute's committees on student chapters and chemical engineering projects brings up to date a popular record of available films much used by chemical engineering departments local sections, and companies in planning technical film sessions. The supplement is keyed to the original code system used in the 1953 publication. Those wishing copies of the supplement or of the original list should make their request to the Executive Secretary of the American Institute of Chemical Engineers, 25 West 45th Street, New York 36, N. Y.

SOUTHWEST'S FIRST HOUDRIFORMER

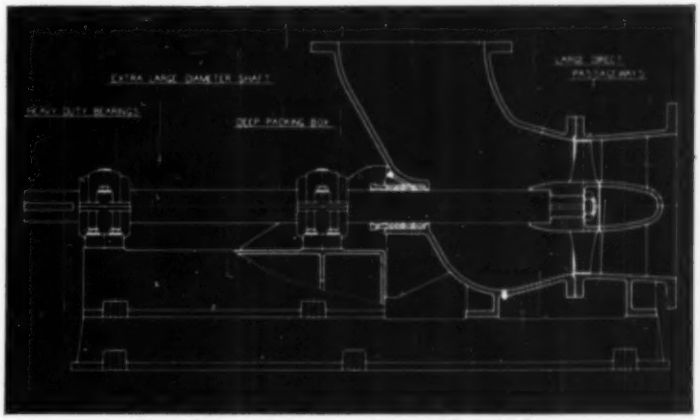
The Houdry catalytic reforming unit in the Southwest is being constructed at a cost of over a million dollars by Blaw-Knox Co. for the Crown Central Petroleum Corp. at their Pasadena, Texas, refinery. The unit will have a 5,550-bbl./day capacity.

REICHHOLD ANNOUNCES PHTHALIC ANHYDRIDE PLANT

Canadian production of phthalic anhydride will be increased 4,000,000 lb. annually by the soon-to-be constructed Reichhold Chemicals Montreal plant. The new plant will cost $750,000. Its output will make Canada virtually independent of foreign sources of phthalic anhydride. The present annual consumption is 14,000,000 lb.



Lawrence 24" Horizontal Circulating Pump of Nickel Alloy Construction



Cross Section of Lawrence Horizontal Propeller Pump

PROPELLER PUMPS FOR THE CHEMICAL and PROCESS INDUSTRIES

Lawrence Propeller or Axial Flow Pumps are widely used to circulate large volumes of liquid or slurry against low heads as in evaporators, crystallizers, etc. This type of pump is particularly well adapted for circulating service because of its simplicity, high efficiency, and low first cost. The flow can be arranged in either direction and the casing turned to any position desired to serve as an elbow. The capacity can be closely regulated by varying the speed—very important in crystallization processes where a uniform velocity must be maintained.

Lawrence Propeller Pumps are made of the metals and alloys best suited for their ability to resist the corrosive and abrasive action of the liquid pumped.

Write for Bulletin 203-6 for summary of acid and chemical pump data.

LAWRENCE PUMPS INC.

371 MARKET STREET, LAWRENCE, MASS.

FUTURE MEETINGS and Symposia of the Institute

MEETINGS **SYMPOSIA**

ANNUAL—NEW YORK, N. Y., Statler Hotel, Dec. 12-15, 1954.

Technical Program Chairman: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.

ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Gas Absorption **Reaction Kinetics**

Biochemical Engineering **Solvent Extraction**

New Processes Utilizing Moving Beds

Business Organization for the Chemical Industry

Deadline Past

LOUISVILLE, KY., Kentucky Hotel, March 20-23, 1955.

Technical Program Chairman: R M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Heat Transfer

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

Propellant Power

CHAIRMAN: R. A. Cooly, Olin Industries Inc., East Alton, Illinois.

Industrial Relations

CHAIRMAN: Samuel L. H. Burk, Dir. Personnel Administration, General Foods Corp., White Plains, N. Y.

Deadline—November 20, 1954

HOUSTON, TEXAS, Shamrock Hotel, May 1-4, 1955.

Technical Program Chairman: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Nucleation Processes

CHAIRMAN: D. W. Oakley, Plant Mgr., Metal & Thermit Corp., 1 Union St., Carteret, N. J.

Flow of Fluids Through Porous Media

CHAIRMAN: H. Dayton Wilde, Mgr. Res. Div., Humble Oil & Ref. Co., Box 2180, Houston 1, Tex.

Azeotropic and Extractive Distillation

CHAIRMAN: Dr. D. E. Holcomb, Dean of Eng., Texas Technological College, Lubbock, Tex.

Chemical Engineering Curricula

CHAIRMAN: Dr. J. W. Mason, Dean of Eng., Georgia Inst. of Tech., Atlanta, Ga.

Deadline—January 1, 1955

LAKE PLACID, N. Y., Lake Placid Club, Sept. 25-28, 1955.

Technical Program Chairman: L. J. Coulthurst, Chief Proc. Designer, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

Process Engineering Organizations

CHAIRMAN: J. F. Thornton, Pres., The Lummus Co., 385 Madison Ave., New York 17, N. Y.

Deadline—May 25, 1955

MEETINGS **SYMPOSIA**

ANNUAL—DETROIT, MICH.—Statler Hotel, Nov. 27-30, 1955.

Technical Program Chairman: T. J. Carron, Supervisor, Chem. Eng. Section, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

Photochemical Processes

CHAIRMAN: Prof. J. J. Martin, Dept. Chem. Eng., Univ. of Michigan, Ann Arbor, Mich.

Biochemical Engineering

CHAIRMAN: Dr. H. O. Halvorsen, Dept. Chem. Eng., Univ. of Illinois, Urbana, Illinois.

Technical Societies Cooperation with Chemical Engineering Industries

CHAIRMAN: Prof. J. B. Phillips, Dept. Chem. Eng., Phys. Sciences Centre, McGill Univ., Montreal 2, Canada.

Deadline—July 27, 1955

LOS ANGELES, CALIF., Statler Hotel, Feb. 26-29, 1956.

Technical Program Chairman: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

Deadline—Oct. 26, 1955

ANNUAL—BOSTON, MASS., Hotel Statler, Dec. 9-12, 1956.

Technical Program Chairman: W. C. Rousseau, Proc. & Sales Eng., Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

Deadline—August 9, 1956

UNSCHEDULED

Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Extraction of Hydrocarbons for Chemical Use from Pipe Line Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Bubble Mechanics

CHAIRMAN: Prof. R. C. Kintner, Dept. Chem. Eng., Ill. Inst. of Tech., 3300 Federal St., Chicago 16, Ill.

Fundamental Mechanisms in Boiling Cavitation and Condensation

CHAIRMAN: R. R. Hughes, Shell Development Co., Emeryville, Calif.

Extraction of Hydrocarbons for Chemical Use from Pipeline Gases

CHAIRMAN: E. Frye, J. F. Pritchard & Co., 210 W. Tenth St., Kansas City 5, Mo.

ONE-DAY ANNUAL SYMPOSIA

New York Section, New York City—October 13, Hotel Statler

South Texas Section, Galveston, Texas—October 22, Galvez Hotel

AUTHOR INFORMATION

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E. Mr. S. L. Tyler, American Institute of Chemical Engineers, 25 West 45th Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended, one copy to the Assistant Chairman of the A.I.Ch.E., Program Committee, address at the top of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. F. J. Van Antwerpen, 25 West 45th Street, New York.

If you wish to present the paper at a particular symposium, request 4 copies of the proposal sending a copy to the Chairman of the symposium.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E., at 25 West 45th Street, New York, a copy of the A.I.Ch.E. Guide covers the essentials required for submission of papers to the A.I.Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The other copies should be sent to the Editor's office. All manuscripts submitted to the A.I.Ch.E. Editor are automatically considered for C.E.P., the A.I.Ch.E. Journal, and the Symposium Series. Presentation at a meeting is no guarantee that manuscripts will be accepted.

Chairman, A.I.Ch.E. Program Committee
George Armistead, Jr., George Armistead & Co.,
1200 18th St., N.W., Washington, D. C.

Assistant Chairman
L. J. Coulthurst, Foster Wheeler Corp.
165 Broadway, New York 6, N. Y.

R. L. PIGFORD TO GIVE 1955 INSTITUTE LECTURE

Robert L. Pigford, professor and chairman of the department of chemical engineering, University of Delaware, has been named the Institute Lecturer for 1955. He will address the meeting in Detroit in November on "Kinetics of Absorption with Chemical Reactions."

Dr. Pigford has distinguished himself as a research chemical engineer, educator, author, and consultant. He is a member of both the Program and Publication Committee and the Professional Guidance Committee of the Institute.

The Institute Lectures, which were initiated to provide the members at each annual meeting with a comprehensive coverage of some essential aspect of chemical engineering, are usually published in expanded form in the Monograph Series of C.E.P.

NEW FERTILIZER PROCESS

A process for the production of homogeneous, granular, free flowing fertilizer that doesn't cake in storage, is being licensed by the Link-Belt Co., Chicago, Ill. The Martinet process was developed by Link-Belt Co., E. Rauh and Sons Fertilizer Co., and Simon J. Martenet.

Formulation of all ratios of fertilizers using such chemicals as anhydrous ammonia and ammonium nitrate is permitted with the process. Close control in the process assures granular, homogeneous and free flowing material with particle size regulation. During the process storage curing is not required and thus an economy in storage facilities while in process is realized. The new product can be stored in bags or in bulk for long periods of time without caking.

E.J.C. INITIATES UNITY PROGRAM

The Engineers Joint Council, an affiliation of 170,000 engineers of major engineering organizations, has made two important organizational movements. In an action to increase the unity of the engineering profession the Council has made constitutional amendments which will add Associate and Affiliate classifications to those engineering groups that do not meet the qualifications for Constituent membership, and who desire admission to the Council. In an action to meet the pressing problems of nuclear engineering, the Council has initiated steps toward an organized program of confronting these problems. An invitation will be extended to prominent scientific societies to participate in this program.

"J.B. seems to operate more smoothly since he decided on TEFLON* made by ETHYLENE **"

* DuPont trade name for tetrafluoroethylene resin**

This amazing material is chemically inert, has excellent dieletric properties, resists heat and cold, is nonadhesive, and possesses great flexural strength. We make it in a great variety of sizes, of the finest quality, and for quick shipment. May our experts help you?

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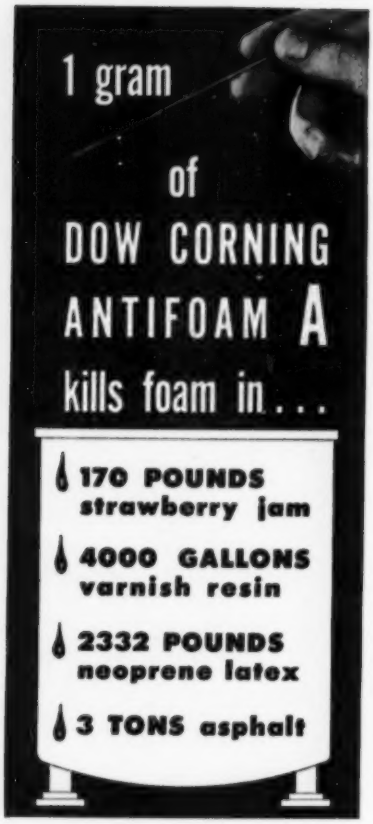

Effective at very low concentrations, Dow Corning Antifoam A Compound is the most economical, the most efficient and the most versatile foam-killer ever developed. Odorless and tasteless, this silicone defoamer is physiologically harmless in foods at concentrations up to 10 parts per million. Thousands of chemical and food processing plants depend on Dow Corning Antifoam A to cut processing time, to save productive capacity now wasted on foam, and to eliminate wasteful and hazardous overflow.

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is a dilutable defoamer containing 30% Antifoam A. It is easily dispersed, equally versatile and equally effective against aqueous foamers. It is safe to use in food processing at concentrations up to 10 parts Antifoam A per million parts of the foamer.

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A.I.Ch.E. COMMITTEE CONDUCTS SURVEY

The fourth annual edition of "Chemical Engineering Faculties," issued by the Chemical Engineering Education Projects Committee of the A.I.Ch.E. is under preparation. A survey is currently being conducted, electing from educational institutions the number of chemical engineers graduated in 1954, availability of graduate chemical engineering curricula, names of the chemical engineering faculty and of the placement officer, A.I.Ch.E. accreditation, and the existence of student chapters of the A.I.Ch.E. This is being conducted by Kenneth A. Kobe of the University of Texas. Previous editions of the publication have found wide acceptance among industrial personnel men.

NATIONAL LEAD ANNOUNCES CUBAN PLANT EXPANSION

A 75% expansion of the United States government-owned nickel plant at Nicaro, Cuba, will be carried out by Frederick Snare Corp. and Merritt-Chapman & Scott Corp. The National Lead Company, through its major interests in the Nickel Processing Corp., which operates the plant, is the operating contractor for the General Services Administration. The Office of Defense Mobilization has authorized investment of up to $43 million in the program.

PHOSPHATE ROCK RESERVE INCREASED

Millions of tons of phosphate rock and shale have been added to the Westvaco Mineral Products existing reserves by the company's recent acquisition of the last known large patented deposit, in Rich County, Ida. Continued operation of Westvaco's four large electric furnaces at Pocatello, Ida., is thereby assured.

INCREASED SULFURIC CAPACITY

With the intent to become a major factor in industrial chemicals in the Midwest, the National Distillers Products Corp. has purchased the Hegeler Zinc Co. of Danville, Ill., according to N.D.'s president, J. E. Bierworth.

To keep pace with the projected growth of industries such as fertilizer manufacturing and steel processing in the midwestern area of Illinois, Iowa, and Kansas, National by annexing Hegeler has added another sulfuric acid producing plant to its three existing plants which produce over 900 tons of sulfuric acid/day.

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to be best!*

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A.I.Ch.E. MEMBERSHIP INFORMATION

S. L. TYLER, Secretary
American Institute of Chemical Engineers
25 W. 45 St.
New York 36, New York

Dear Sir: Please send me information regarding membership requirements. 9-54

Name: _____
Age: _____
Address: _____
City: _____
Zone: _____
State: _____

Third Convention of U.P.A.D.I

(*Continued from page 46*)

B. Revise the Code of Ethics for Engineers to make positive statements rather than the present negative approach.

C. Revise the organization on Standards for the American countries.

3. From the Committee on Relationships:

A. Encourage participation by younger engineers in the work of U.P.A.D.I.

B. Get ads in the Bulletin to help finance the work of U.P.A.D.I.

C. Encourage and help to find means to finance trips by engineers from one country to another.

D. Encourage and endeavor to finance lectures and chart courses by distinguished engineers in various countries.

E. Endeavor to get additional financial support from private institutions and companies.

F. Endeavor to provide scholarships for the improvement of engineering teaching.

G. Recommend that each country issue a commemorative stamp for Pan American Engineer's Day.

H. Develop a flag and emblem for U.P.A.D.I.

I. Recommend that July 20 be Pan American Engineers' Day.

4. From the Committee on Technical Matters:

A. Recommend joint conferences with other engineering organizations.

B. Recommend that "mixed" committees be formed to study inter-American problems involving transportation (i.e., roads) and power.

C. Improve relations among engineering schools by exchange of professors.

D. Recommend that at least one professor be a delegate from each country to future U.P.A.D.I. meetings.

E. Educational authorities should include city planning as a course in all engineering schools.

5. From the Committee on Budget.

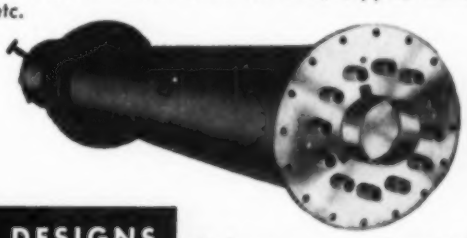
A. A budget of $50,000 was adopted.

In summing up the U.P.A.D.I. convention it is believed that if action can be taken on the resolution aimed at effecting a definitive program, U.P.A.D.I. will make progress. And a good starting point toward such progress will be specific programs for the improvement of Pan American engineering education and for aiding inter-American communication through better roads.

THE ANSWER TO YOUR EXCHANGER PROBLEM MAY BE *HERE*

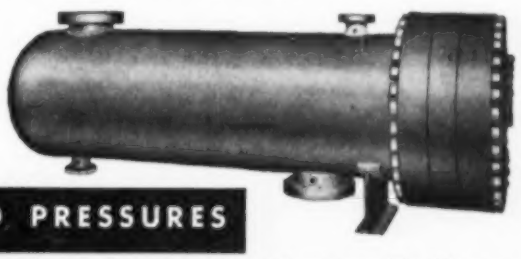
SPECIAL MATERIALS

If your requirements call for special materials of construction, Whitlock can help you. Here's just one example — a graphite tube side, steel shell side exchanger. This exchanger utilizes chemically inactive graphite which has been resin impregnated. Units of this type are particularly adapted to process operations where highly corrosive fluids must be handled. We also regularly work with other anti-corrosive materials: stainless steel, copper, nickel, Monel, Hastelloy, etc.



SPECIAL DESIGNS

Perhaps you need special design techniques — if you do Whitlock can help you. For example, this falling film evaporator (with top channel removed) was carefully designed with a maximum elevation difference in tube ends of plus or minus 0.005" to assure proper feed distribution to individual tubes. Whitlock Engineers are thoroughly experienced in designing exchangers for difficult operating conditions.



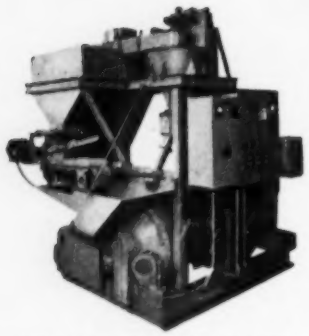
ELEVATED PRESSURES

Perhaps you need an exchanger for elevated pressures like this rugged cooler, built for design pressures of 600 p.s.i.g. on both shell and tube sides. Its "Monobloc" (solid disc) channel is about 7" thick to take care of the working pressure. The 1" thick shell was stress-relieved after fabrication. We are regularly manufacturing shell and tube units (for pressures to 3000 p.s.i.g.) and shell and coil units (for pressures in excess of 5000 p.s.i.g.).

Whitlock

For recommendations write The Whitlock Manufacturing Company, 97 South Street, West Hartford 10, Conn.

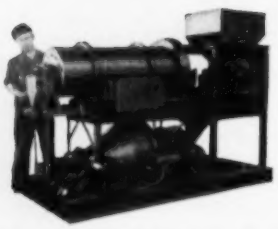
Designers and builders of bends, coils, condensers, coolers, heat exchangers, heaters, piping, pressure vessels, receivers, reboilers.



DRY GRINDING UNIT

Make power connections only and the Hardinge Dry Grinding Unit is ready to perform. Self-contained and portable, 7' 8" high. Complete with Constant Weight Feeder, Conical Mill, "Gyrotor" Air Classifier, dust collector, product collector and "Electric Ear" grinding control.

"Packaged Pulverizers"



WET GRINDING UNIT

Make power and water connections only and the Hardinge wet grinding unit is ready to perform. Self-contained and portable, 6½' high. Includes Conical Mill, Counter-Current Classifier, launders, feeder, pump and "Electric Ear" grinding control.

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News of the Field
FROM LOCAL SECTIONS

East Tennessee. The metallurgy of welding as it can affect chemical engineering plant equipment construction, was the subject of the Aug. 25 meeting addressed by Professor Gordon C. Williams, head of the department of chemical engineering, University of Louisville. The physical mechanisms that take place when carbon steel is heated over the range of temperatures required by welding were compared with the mechanisms for higher strength alloyed steels and stainless steels.

Meetings scheduled for the remainder of the year include a talk on sieve-plate distillation by E. M. Schoenborg, head of the department of chemical engineering at North Carolina State College, and on catalysis by A. J. Teller of Fenn College.

—M. L. GERNERT

NEW YORK ANNUAL MEETING BEING PLANNED

Some inkling of the good fellowship sure to permeate the forthcoming New York Annual Meeting (Dec. 12-15) can be seen in the countenances of the men responsible for plans. Hosts for the meeting will be the New York and New Jersey sections. Shown in the photograph are (center) Howard L. Malakoff, general chairman; (left) T. H. Kelly, New Jersey co-chairman; and (right) Frank B. White, New York co-chairman.

According to the latest information, the following events are being planned: a cocktail party, buffet supper, Sunday afternoon panel session on "What the Young Chemical Engineer Needs from the A.I.Ch.E.," six symposia, twelve plant visits, special luncheons, the Awards Banquet, and a gala dance and parties. As to the ladies, what more need be said at this time than that the meeting will be held in the world's center of fashion, theater, opera, TV, radio, music . . . shopping . . . !

Pittsburgh. At the annual meeting of the Pittsburgh Section new officers were elected for the 1954-1955 season. They are: *Chairman*—Jerry McAfee, Gulf Research and Development Co. *Vice-chairman*—R. S. Rhodes, Koppers Co. *Treasurer*—F. W. Dittman, Rust Process Design Co. *Secretary*—J. R. West, Mellon Institute of Industrial Research.

—J. R. WEST

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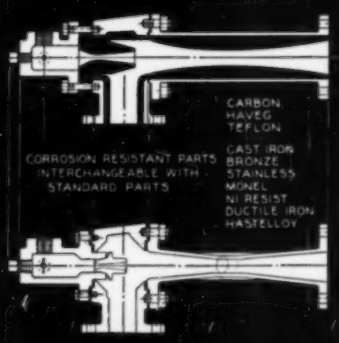

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News of the Field

FROM LOCAL SECTIONS

New Jersey. Under the sponsorship of the New Jersey Section, a series of five lectures titled "Design for Profit" will be given during the months of October and November at the Clinton School in Plainfield, N. J. The cost is $2.00 a lecture, $6.00 for a set of lectures for members, and $8.00 a set for others. The lectures will run from 8 P. M. to 10 P. M. Checks may be made payable to Joseph D. Stett, dept. of mechanical engineering, Rutgers University, New Brunswick, N. J.

The lectures will cover the following subjects:

Oct. 19—The Principles of Economic Balance by John Happel, department of chem. eng., New York University

Oct. 26—Application of Economic Balance to Plant Design by John Happel

Nov. 2—Application of Economic Balance to Plant Operation by John Happel

Nov. 16—Equipment Cost Estimating by Cecil H. Chilton, *Chem. Eng.*

Nov. 23—Management Review by V. R. Bechtel, Amer. Cyanamid

—R. J. BECHTEL

Southern California. A 1,600 square mile chemical reaction chamber in Southern California is a major factor in the production of fog in that basin area, according to Lauren B. Hitchcock, president and managing director of the Southern California Air Pollution Foundation, at an address before the Aug. 17 meeting of the A.I.Ch.E., Dr. Hitchcock expressed his opinion that the boundary conditions of mountains on three sides capped by a low-air inversion layer in lower California provide a restricted volume in which air pollutants would be concentrated because of low air speeds. This thin layer of air receives pollution from automobiles and trucks, backyard incinerators, and industrial exhausts. Solar irradiation produces photochemical reactions between the hydrocarbons, nitrogen oxides and ozone.

—F. G. SAWYER

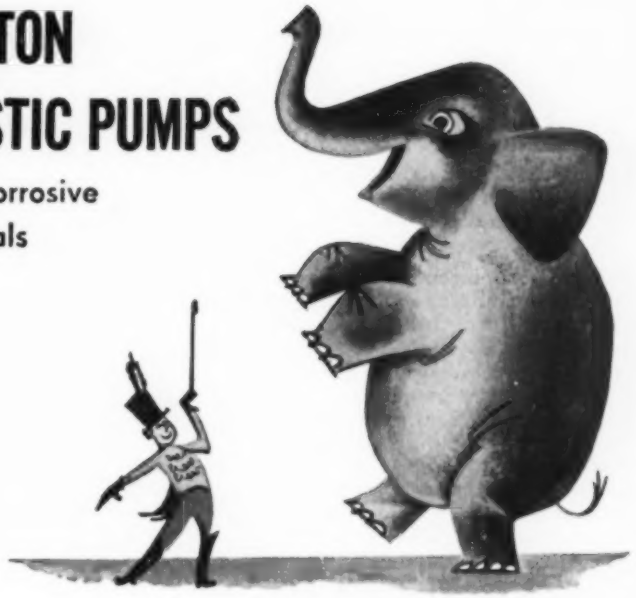
South Texas. Chemical engineers and their families from this major industrial area enjoyed an afternoon of barbeque, beer and games at the H & H Ranch, near Houston. This annual outing took place September 12th.

Wives of members of the South Texas Section of A.I.Ch.E. have their own organization—the "Auxiliary of the A.I.Ch.E." which holds regular meetings throughout the year. This unique organization is heralded in this month's News and Notes (page 88).

—C. L. FITZGERALD, JR.

VANTON PLASTIC PUMPS

tame corrosive chemicals



Flex-i-liner **PUMPS** are becoming industry's standard for those difficult to handle corrosive solutions and abrasive slurries, such as HCL, HF, NaOH, H_2SO_4, distilled H_2O, $FeCl_3$, HCOOH, and $Al_2(SO4)_3$, because their unique design eliminates stuffing boxes, shaft seals, gaskets and check valves.

NO METAL IN CONTACT—The only parts in contact with the fluid being pumped are the outer surface of the durable precision molded flexible liner and the inner surface of the pump body block, both of which are available in a wide selection of corrosion and contamination resistant materials.

FLEX-I-LINERS:

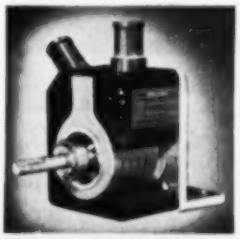
● Pure gum rubber ● Natural Rubber ● Neoprene
● Hycar ● Buna N ● Silicone ● Vinyl ● Compar

BODY BLOCKS:

● Polyethylene ● Bakelite ● Buna N
● Lucite ● Unplasticized PVC

● Available in stainless steel for special applications.

Flex-i-liner Plastic Pump



NO STUFFING BOX—Elimination of stuffing boxes, packing glands and shaft seals, avoids the possibility of external leakage and prevents contamination of the transferred liquid by oil or grease.

SELF PRIMING—Vanton self priming plastic pumps give immediate operation in any position.

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OUR CORROSION RESISTANT PRODUCTS FOR FLUID HANDLING include a complete line of Buna N and Natural Hard Rubber centrifugal pumps, valves, pipe and fittings. Bulletin BHR on request.

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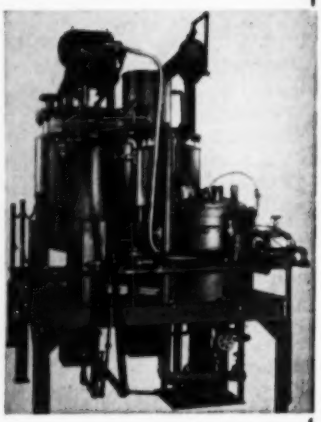

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- If no longer needed, there is always a ready market at a favorable price in the used equipment field.
- And there are other factors — the efficiency of clarification, cake recovery, extraction, washing, drying and thickening — all in one piece of equipment.

Typical of more than 150 Shriver Filter Presses installed in the plant of a leading producer of fine chemicals over the past 40 years. Included are presses with washing and non-washing type filter plates, of cast iron, stainless steel, bronze, aluminum, rubber and wood.

for all of these and more—you can't beat

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Richardson Agencies, Ltd., Toronto, Ont., Montreal, Que.

PEOPLE

A new partner in the firm of Singmaster & Breyer, which will shortly complete twenty-eight years of service to the chemical and metallurgical processing industries, is **Thomas R. Young.** Mr. Young's fifteen years' production, design, and management experience covers a broad field of chemical engineering operations in heavy and fine chemicals, electrolysis, and extractive metallurgy. He spent seven years with the Du Pont Co., his last assignment there being a production supervisor of its tetraethyl lead plant. More recently he has been project engineer for Singmaster & Breyer. Mr. Young holds a B.S. (1937, and a Ch.E. (1938) from Princeton University.

Thomas H. Vaughn, vice-president of the Colgate-Palmolive Co. in charge of research and development, left for Europe on Aug. 21 to attend the First International Detergent Congress. The plan called for him to serve as president of the technical section of the Congress.

E. L. Clark has accepted the position of director of pilot plant laboratories with the Israel Mining Industries effective Aug. 1. He is located at Haifa, Israel.

The promotion of **George T. Atkins** to the position of engineering associate at the Baytown, Tex., refinery has been announced by the engineering division of Humble Oil & Refining Co. His new assignment will cover the development of design criteria and the actual design of some of the larger projects being considered for Baytown refinery.

Mr. Atkins received his B.S. degree in chemical engineering from Washington University, St. Louis, in 1929.

C. A. Bishop, research associate with the United States Steel Corp., was recently promoted to the post of director of chemical process and chemical engineering development. For many years Dr. Bishop served as secretary of the A.I.Ch.E. Pittsburgh Section.

—Reported by J. R. West, Secretary, Pittsburgh Section

Charles E. Dryden, assistant chief in the chemical engineering department at Battelle Memorial Institute, Columbus, Ohio, has been appointed assistant professor in the department of chemical engineering at Ohio State University. He will assume the university post on Oct. 1. Dr. Dryden, who has been at Battelle since 1948, served as research engineer with the Silmo Corp., Vineland, N. J., from 1935 to 1941 and was head of the process development group, Nopco Chemical Corp., Harrison, N. J., from 1942 to 1948.

N. W. SNYDER

Nathan W. Snyder has been appointed associate professor of chemical engineering at the University of California, Berkeley, Calif. He has been acting as a consulting chemical engineer for Kaiser Engineers, Oakland, for the past year.

Through an organizational change **Robert E. Baker** has been appointed as chemical engineer in the engineering department of the Hooker Electrochemical Co., Niagara Falls, N. Y. He went to Hooker in mid-1953, immediately after his graduation from Cornell University. His first assignment at Hooker was in the process study group.

Promotion of **Aldrich Syverson** to a professorship in the department of chemical engineering, effective Oct. 1, has been announced at Ohio State University, Columbus, Ohio. Dr. Syverson was associated with the B. F. Goodrich Chemical Co. from 1942 to 1948 and taught at the University of Syracuse before joining the Ohio State staff in the rank of associate professor in 1950.

A recent appointee to the staff of the research and development department of American Viscose Corp., Marcus Hook, Pa., is **John D. Cruikshank,** a research engineer, who is serving in the experimental spinning pilot plant. He holds a B.S. degree in chemical engineering from Carnegie Institute of Technology.

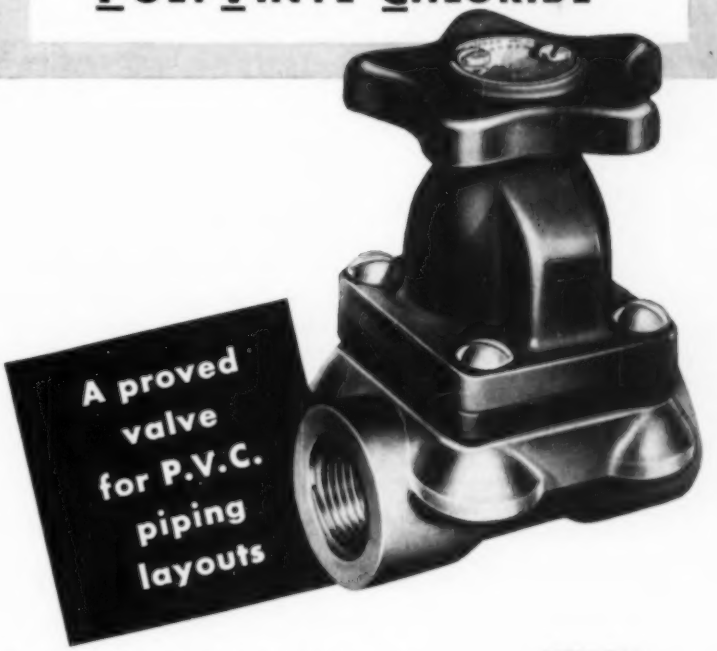
Alexander Sesonske has been appointed associate professor of chemical engineering at Purdue University. Dr. Sesonske has been a staff member of Los Alamos Scientific Laboratory, University of California, since 1950.

Announcing

HILLS-McCANNA

Saunders Patent

DIAPHRAGM VALVES with bodies of POLYVINYL CHLORIDE



With the addition of valves with unplasticized, rigid polyvinyl chloride (P.V.C.) bodies, Hills-McCanna further expands the most extensive line of corrosion-resistant valves. Now, the corrosion resistance and rugged durability of P.V.C. is available in a valve of proved and accepted design.

Hills-McCanna P.V.C. valves are available in handwheel or lever operated types or with air cylinder, diaphragm motor or electric motor operators for remote or automatic control. Sizes range from ½" through 2". All regular diaphragm materials are available (rubber, Neoprene, Kel-F, Teflon, etc.). Screwed ends are standard. Slip fits available on special order.

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"Kerodex" offers practical and effective protection *before* the damage is done. It is nonirritating and nonsensitizing. It may be applied with equal safety to the face, hands or any other area of the skin, keeping pores and follicles free from foreign matter.

"Kerodex" does not smear. It does not affect materials handled, nor is it affected by them. It is easy to apply, economical and highly acceptable to the user.

"Kerodex" provides a vital safety measure for the maintenance of high production levels.

Maximum Protection

"Kerodex"® is supplied in two types, and a series of creams are available to protect against: *water-soluble* irritants such as acids, alkalis, soaps, detergents, and *water-insoluble* irritants such as paints, enamels, cleaning fluids.

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in Floors, Tanks, Sewers, Towers, etc.

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DELRAC POLYESTER CEMENT

Delrac Polyester Resin Cement resists most acid solutions, including oxidizing acids, mild alkalies and many solvents. Used at temperatures up to 250° F. White in color.

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Resins, Corrosion-Resistant Cements and Coatings, Concrete Admixtures, Protective Tape Pipe Coatings

KOHLINS ADVANCED BY BLAW-KNOX

W. D. Kohlins, New York District sales manager of Buflovak Equipment Division of the Blaw-Knox Co., has been appointed Director of Engineering of the same division with offices in Buffalo, N. Y. Early in his career he was associated with the U. S. Gypsum Co., Mathieson Alkali Works, and the Swenson Evaporator Co. Mr. Kohlins has been active in the affairs of A.I.Ch.E. and in other chemical engineering projects.

For the Institute, Mr. Kohlins is at present serving as vice-chairman of the Admissions Committee and is on the Advisory Board of the Vocational Guidance Committee. He is also a member of the International Relations Committee. At present he is a representative on U.P.A.D.I. In 1951 he was chairman of the New York Section.

For E.C.P.D. he served as chairman of the New York Engineers Committee on Student Guidance. At one time Mr. Kohlins was secretary of the Chemical Equipment and Sales Engineers Association.

The promotion of **A. M. Souby** to research specialist in research and development division at its Baytown, Tex., refinery has been announced by Humble Oil & Refining Co. In this capacity Mr. Souby will work on catalytic conversion with emphasis on the application of chemical kinetics to process development and design. He graduated at Vanderbilt University in 1938 and joined research and development at Baytown in 1939.

The Pure Oil Co., Chicago, Ill., has announced the accession of **Kenneth M. Watson,** its director of research, to the vice-presidency, effective Aug. 1. The new vice-president for research and development has worked in the petroleum industry for practically twenty years, and during World War II he served the government as chairman of the technical committee of the Neches Butane Products Co., and as consultant to the War Production Board. In 1948 he received the William H. Walker Award of A.I.Ch.E.

Fabian Bachrach

Dr. Watson is the author of chemical engineering texts. He received his doctorate at the University of Wisconsin where he also taught. He joined Pure Oil in August, 1952, as director of research at the companys' research and development laboratories in Crystal Lake, Ill.

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J. H. Rothschild has taken over new duties as president, Chemical Corps Board, Army Chemical Center, Maryland. Colonel Rothschild was formerly Chemical Officer, Far East Command.

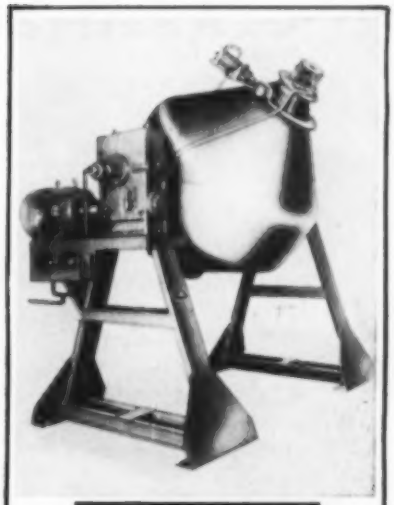
Appointment of **Charles R. Holman** as assistant divisional manager of the Newark, N. J., paint division of the Pittsburgh Plate Glass Co. has been announced. Prior to this appointment Mr. Holman had served as manager of the Selectron department at the Springdale paint division for thirteen years. In 1938, as a chemical engineer, he became associated with Pittsburgh Plate Glass and served in the research department of the Columbia-Southern Chemical Corp., Barberton, Ohio. Columbia-Southern is a wholly owned subsidiary of the Pittsburgh Plate Glass Co.

Wayne S. Dodds has joined the central laboratories of General Foods in Hoboken, N. J., as assistant laboratory director in engineering research and commercial development. Most recently an executive director of the chemical engineering laboratory of Northwestern Technological Institute, Evanston, Ill., Dr. Dodds received a B.S. degree from Iowa State College and also holds a Ph.D. from Northwestern Technological Institute.

An addition to the staff of Stanford Research Institute, Palo Alto, Calif., as an assistant chairman of the chemistry department is **Allyn C. Miller,** former technical operations supervisor of California Research and Development Co. He will supervise project work in the chemical, metallurgical, and ceramic engineering section, as well as in air research. Before joining the Livermore research organization, where he was doing work for the A.E.C., Mr. Miller was president of Mill-Hall, Inc., manufacturers of chemical specialties at Richmond, Calif. He was previously a process design engineer with Shell Chemical Corp., San Francisco, and before that a development engineer with Du Pont at Wilmington, Del.

An appointment to research work became effective Aug. 1, when **Joseph E. Ross** was made head of Experimental Spinning at the American Viscose Corp.,

(Continued on page 85)



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CHEMICAL ENGINEER—Age 26. B. Ch. E. 1950. Four years' experience in plant engineering and maintenance work. Desire position offering opportunity and responsibility. Box 8-9.

SENIOR CHEMICAL ENGINEER—D.Ch.E. June 1955, M.Ch.E., P.E. Eleven years' concentrated experience process design and development, responsibility, supervision, in petroleum, heavy organics, natural gas. Prefer responsible supervisory position metropolitan New York area. Box 9-9.

CHEMICAL ENGINEER—B.S.Ch.E. Petroleum refining experience: ten years in process development and pilot plant operation and four years in economic analysis of plant operations. Desire position with future in a progressive small or medium-sized company. Prefer Far West. Married, age 35. Box 10-9.

NEW PRODUCT DEVELOPMENT—B.S.Ch.E. Age 39. Seventeen years' varied experience in research, development, production, and sales. Have successfully developed new products. Desire administrative or executive position. Box 11-9.

CHEMICAL ENGINEER—B.S. 1950. Age 32, married. Four years' pilot plant experience fatty acid research and development. Desire Far West, Southwest or Deep South location. Box 12-9.

CHEMICAL ENGINEER—M.S. Seven years' intensive industrial experience; technical service in major petroleum refinery, process design and economic studies on inorganic and petrochemical operations for construction company. Want permanent, responsible position. Eastern location preferred. Box 13-9.

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CHEMICAL ENGINEER—M.S. Age 33, married, veteran. Seven years' extensive experience process and project engineering, manufacturing operations at semi-works and plant level. Supervisory and administrative background. Desire position offering responsibility and opportunity. Box 16-9.

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Advertisements in the Classified Section of Chemical Engineering Progress are payable in advance at 15c a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section of Chemical Engineering Progress agree that all communications will be acknowledged; the service is made available on that condition. Boxed advertisements are available at $15 a column inch. Size of type may be specified by advertiser. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 15th of the month preceding publication.

PEOPLE

(*Continued from page 83*)

Marcus Hook, Pa. Mr. Ross, a chemical engineering graduate of Rose Polytechnic Institute, Terre Haute, Ind., goes to American Viscose from the Engineering Experiment Station, Georgia Institute of Technology, where he acted as a technical administrator on chemical and mechanical engineering projects. Mr. Ross served during World War II as an Army officer in research and development at Edgewood Arsenal, Md.

The appointment of **Elwood I. Clapp, Jr.,** as assistant to the manager of American Cyanamid Co.'s new product development department was recently announced. Formerly a member of the market research department and previous to that a chemical engineer at the company's Stamford research laboratories in Stamford, Conn., Mr. Clapp was graduated from the University of Maine in 1943 with a B.S. degree in chemical engineering and pursued postgraduate studies at M.I.T. until 1945 when he joined Cyanamid.

LaVern O. Streitmatter, who has been production assistant to the assistant general superintendent of furnace plants of Victor Chemical Works, has been promoted to superintendent of the Victor plant in Silver Bow, Mont. Mr. Streitmatter, a chemical engineer who joined Victor when he came out of military service in 1946, went to Montana several months ago from the company's general offices in Chicago. In his eight years of association with Victor he served at the Chicago Heights, Ill., and Tarpon Springs, Fla., plants, and in the executive offices in technical and managerial capacities.

Effective Sept. 1, **Desmond B. Hosmer** became manager of the Anniston, Ala., plant, organic chemicals division, Monsanto Chemical Co. A native of Michigan, Hosmer was employed by Monsanto immediately upon his receiving the B.S. degree in chemical engineering in 1937 from the University of Michigan. First in the analytical laboratory at the W. G. Krummrich plant, and prior to his appointment as assistant plant manager there in 1950, he had been plant investigation group leader and operating superintendent.

Charles E. Wicks, who has completed work for the Ph.D. at Carnegie Institute of Technology, has accepted a position as assistant professor of chemical engineering at Oregon State College, Corvallis, Ore.

(*Continued on page 86*)

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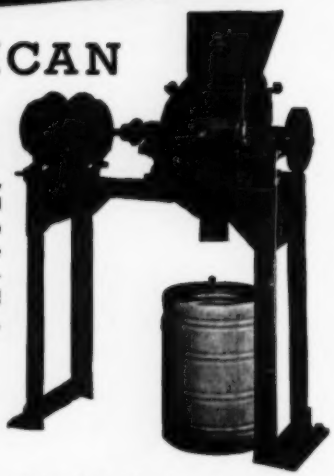

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PEOPLE

(*Continued from page 85*)

The recent appointment of **Robert M. Cornforth** as manager of refinery sales for Kaiser Engineers division of Henry J. Kaiser Co., Oakland, Calif., has been announced. Mr. Cornforth, who will specialize in matters pertaining to the petroleum industry, was formerly vice-president in charge of sales for the W. M. Barnes Co. of Los Angeles, Calif., and Toronto, Canada. During World War II, he was in the U. S. Army Corps of Engineers assigned to the Petroleum Administration for War. He organized and directed the technical oil mission to Germany and was special assistant to the director of Foreign Refining of the P.A.W. Prior to the war, Cornforth was with the Standard Oil Company of Indiana as a chemical engineer for five years, and upon leaving the service became associated with the Houdry Process Corp., Philadelphia, where he was manager of sales.

John S. Cort, Jr., has been serving as sales manager of chromium chemicals division of Diamond Alkali Co., Cleveland, Ohio, since early this year. Cort was formerly at the company's Kearny, N. J., chromium chemicals plant where he had been assistant manager for the past five years. Previously, he had been with the Diamond silicate plant at Cincinnati. Graduated from the University of Michigan in 1935, he joined the Pennsylvania Salt Manufacturing Co., Natrona, Pa., and subsequently was engaged in various engineering and production capacities with Garco Products, Inc., Ford City, Pa., and Houdry Process Corp., Paulsboro, N. J. In 1944 he joined Diakel Corp., Cincinnati, as a process engineer, later becoming chemical director of this company's catalyst plant, holding this position until the plant was sold by the War Assets Administration to Davison Chemical Corp. in 1947, when he joined Diamond's Cincinnati silicate plant.

H. J. Karakas, formerly field engineer, has recently become manager of the newly created Eastern Seaboard sales division of the Pfaudler Co., Rochester, N. Y. Prior to his association with Pfaudler, Karakas, a chemical engineer, was Eastern sales manager for the process engineering division of the Patterson Foundry & Machine Co., East Liverpool, Ohio. In his new post he will be responsible for general sales, including process engineering and heavy process equipment for the chemical, petrochemical and allied industries in the area covered by the company's New York, Boston, Philadelphia, and Washington, D. C., offices.

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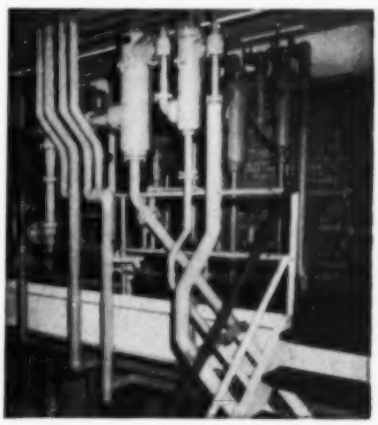

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A.I.Ch.E. News And Notes

Nomination Committee will turn in its first slate of candidates, according to the new constitutional amendment, seven weeks before the annual meeting.

W. I. Burt is Chairman of the group this year, which has as members L. C. Kemp, W. L. Faith, R. H. Price, & Lee Van Horn.

Procedure as noted in the new proviso allows for nomination by petition . . . all that is required is a petition signed by fifty Members or Associate members, plus the candidates' willingness to serve.

All such nominations, though, must be with the Secretary of the A.I.Ch.E. not later than nine weeks prior to the annual meeting . . . which means by Oct. 10.

The slate of candidates from the committee must contain all names suggested by petition, & the ballot to members must be mailed by Nov. 1.

To those groups planning nominations of favorite sons, the nominating committee sends a plea for promptness because of the tight scheduling. In addition, since inevitably some petitioned candidate will also be the committee's choice, a letter to the committee chairman, Bill Burt, telling of nominating plans would be in order. This will insure on the ballot the best possible selection of names.

E.J.C. activities (A.I.Ch.E. is a member) have increased in tempo in recent months . . . on the fire involving the Institute is the creation of a roster of engineers for the National Science Foundation.

Societies in E.J.C. were asked to edit a classification list of N.S.F. for their particular branch of engineering . . . when finished a questionnaire will be sent to all listed in "Who's Who in Engineering" . . . purpose is to create a "finders list" of men who are both expert in a field & who can recommend other experts in the same field.

Above is all part of the original task, assigned to N.S.F. when it was created by Congress to create a roster of scientists and engineers in the U. S.

Another E.J.C. plan involving us is a combined effort of all engineering groups in the atomic energy field.

Hope is that sometime in 1955 a Congress on nuclear engineering will be held, representing the joint effort of all the engineering and scientific disciplines involved in the field.

Engineering Societies Building studies are more active than ever . . . task force is now writing a comprehensive report on locations, costs, manpower, etc., for submission to the presidents of the five engineering societies.

A.I.Ch.E. Research Committee, under the chairmanship of Walter Lobo, is preparing to distribute its second annual report . . . subject is tray efficiency . . . three schools are studying the problem . . . University of Michigan, University of Delaware, & North Carolina State College.

Reports have been prepared by all three & will be distributed to those companies which gave support to the research program.

Report from Brymer Williams group at Michigan covers the determination of tray efficiencies in absorption, & in stripping, as affected by properties of the physical system . . . Ed Schoenborn at North Carolina State College is directing a study on the effect of physical properties of systems on tray efficiencies during distillation . . . & Jack Gerster et al. at Delaware are determining the effect of column operation & design variables upon plate efficiency.

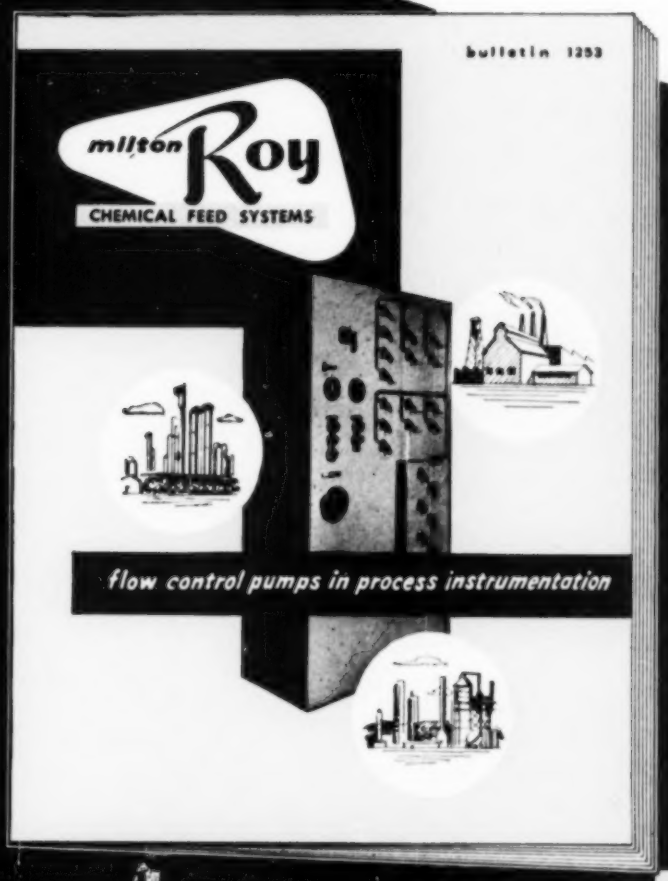
Texas again, this time an A.I.Ch.E. wives' auxiliary . . . as far as we know the first in our history . . . Mrs. R. A. Jensen is chairman . . . Mrs. W. J. Butler, secretary, and Mrs. Eldon A. Siegman, treasurer . . . an extensive program is planned stretching from October right through June & featuring a Valentine supper dance, family picnic, & of course the A.I.Ch.E. National meeting this coming May in Houston.

If you missed our announcement last month here it is again . . . the A.I.Ch.E. is in new headquarters at 25 West 45th St. . . . new telephone is COlumbus 5-7330.

Wonder what films to show at local sections, student chapter meeting, etc.? . . . A.I.Ch.E. has listings of rated films plus all information to get them . . . supplemental revision has been made by Marriott Bredekamp working on the project for the Chemical Engineering Education Projects and Student Chapters committees . . . a note to the Secretary will bring it to any member.

F.J.V.A.

new bulletin
flow control pumps in process instrumentation



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See the MILTON ROY EXHIBIT — BOOTHS 131-136, First International Instrument Congress and Exposition, PHILADELPHIA — SEPTEMBER 13-24, 1954

How to SUSPEND SOLIDS UNIFORMLY

This pilot plant mixer is working at top efficiency.

The turbine impeller is turning just *fast* enough to create the *turbulence* needed to pick up solid particles from the tank bottom and set them in motion.

The impeller is just *large* enough, in relation to the tank, to set up a strong over-all *flow*, moving particles rapidly and evenly throughout the fluid mass.

Less power input would not distribute the particles evenly. More power, in the form of added speed or turbine area, would not do the job any better than it is being done now.

The slightest deviation from *top efficiency* shows up at once on the curve plotted by this Mixco engineer.

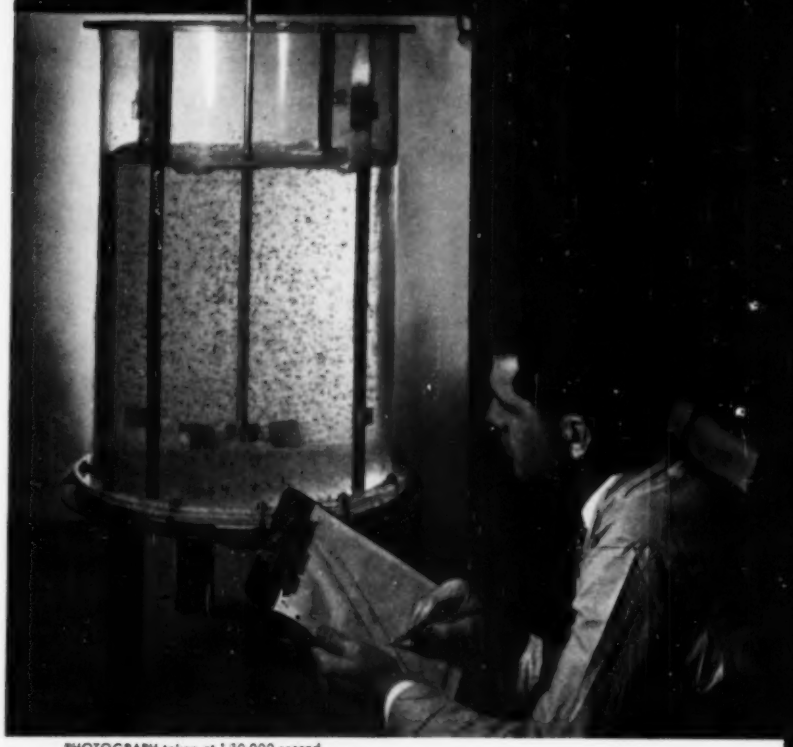
Save time on any mixing job—By using calibrated impellers for his test runs, he always knows his power input. By knowing what the calibrated impellers will do under all conditions, he can extend his optimum impeller size-speed ratio up to a tank size of fifty gallons, five thousand gallons, *five million* gallons—with pinpoint accuracy.

He can double-check his findings, with commercial-scale LIGHTNIN Mixers in test tanks 70,000 gallons big, for high precision.

He can save you weeks, perhaps months, of research and pilot plant work on *any* fluid mixing operation.

Finally, he can guarantee you maximum results, with a LIGHTNIN Mixer selected for the exact power-speed-torque combination your process needs.

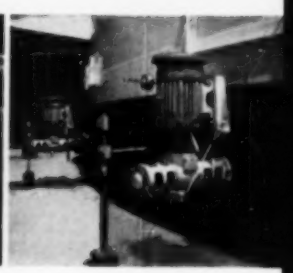
If you'd like to know more about engineered fluid mixing—how it results in a better reaction, a more uniform product, savings in process time and cost . . . how it is applied to liquid-liquid, solid-liquid, or gas-liquid systems . . . how it gives you results that are *guaranteed*—just call in your LIGHTNIN representative. Or write us today.



PHOTOGRAPH taken at 1/10,000 second.

BIG MIXING JOBS can be done quickly, efficiently, with a top entering turbine-type LIGHTNIN Mixer. Any open or closed tank can be fitted with a unit like this. Hundreds of power-speed combinations are available, ranging from 1 to 500 HP input.

DO HUNDREDS of mixing jobs efficiently, at low cost with LIGHTNIN Portable Mixers. Electric or air motors, direct or gear drive. More than 30 standard models. Sizes ⅛ to 3 HP. Full choice of motors, materials.



IN VERY LARGE TANKS, you can mix, blend, circulate, suspend solids, with a LIGHTNIN Side Entering Mixer—faster and more cheaply than by any other method. Sizes from 1 to 25 HP, for tanks as big as 6 million gallons.

- ☐ DH-50 Laboratory Mixers
- ☐ DH-51 Explosionproof Laboratory Mixers
- ☐ B-102 Top Entering Mixers (turbine and paddle types)
- ☐ B-103 Top Entering Mixers (propeller type)
- ☐ B-104 Side Entering Mixers
- ☐ B-105 Condensed Catalog (complete line)
- ☐ B-107 Mixing Data Sheet
- ☐ B-108 Portable Mixers (electric and air driven)

MIXING EQUIPMENT Co., Inc.

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MIXCO fluid mixing specialists